Aircraft METAL WORK

U.S. Bureau of naval personnel

1945 EDITION

NAVY TRAINING COURSES

AIRCRAFT METAL WORK

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PREFACE

This book is written for the enlisted men of Naval Aviation. It is one of a series of books designed to give them the necessary information to perform their aviation duties.

A knowledge of aircraft metal work is of primary importance to Aviation Metalsmiths. How to bend, form, fasten and repair airplane structures according to the latest and best practices is their chief concern.

Starting with a discussion of sheet metal processes and the forming of aluminum, the book continues with explanations of aircraft riveting, fasteners, structural repairs, repairs of tanks and tubing. It concludes with a section on plastics.

As one of the NAVY TRAINING COURSES, this book represents the joint endeavor of the Naval Air Technical Training Command and the Training Courses Section, Bureau of Naval Personnel.

TABLE OF CONTENTS

AIRCRAFT METAL WORK

CHAPTER 1

METAL PROCESSES

KNOW YOUR AIRCRAFT METALS

When the Wrights, Langleys and other pioneers of aviation coaxed their airplanes into the air, you could see more fabric flying than at a piece-goods sale in Macy's basement. But times have changed. Fabric has given way in aircraft manufacture. Today's battleships, cruisers, and destroyers of the sky are made mostly of thin sheet metal.

That is why Naval Aviation needs men with a knowledge of metals and metal work. To understand maintenance and repair of airplane structures, you'll want to start with an investigation of basic sheet metal processes.

SO, ready or not, HERE YOU GO!

When a piece of sheet iron is coated with zinc, you have a piece of GALVANIZED IRON. The zinc coating protects the iron sheet from corrosion. Galvanized

iron and aluminum are the two kinds of sheet metal with which you, as an Aviation Metalsmith, are chiefly concerned.

It is easy to see why you'll be working a lot with aluminum. Aircraft today use more aluminum than any other metal. But what about galvanized iron? The answer is that galvanized iron is much used in laying out templates in aircraft sheet metal work, and is also a stand-by for general shop work. So you might as well bone up on this basic material even though you may already be somewhat familiar with it.

Galvanized iron comes in a number of standard thicknesses, widths, and lengths. The thicknesses are expressed in terms of GAGES—28 gage, 24 gage, and so on. The HIGHER the gage number, the THINNER the piece of galvanized iron.

The sheet iron is coated with zinc by a plating process. The first step is to dunk the sheet steel into a bath of hot sulfuric acid to clean it. Next it is rinsed with running water. Then comes the plating process itself which is accomplished either mechanically, by dipping the metal in molten zinc, or electrically. The point is to get the zinc onto the steel.

The thickness of the zinc coating is regulated by a series of adjustable rollers. The sheets of steel are run through these rollers as soon as they pass from the molten zinc.

THREE COMMON SEAMS

While there are many seams used to join pieces of galvanized iron, the three most common and useful ones for you as a metalsmith to learn are these.

The simple LAP seam.

The GROOVED seam.

The STANDING seam.

The easiest of these three is the simple LAP seam. All you do is lap one piece of stock over another. You can fasten the seam either by RIVETING or SOLDERING.

Or you can combine the two methods, depending on the nature of the job.

If the seam will have to bear up under STRESS, you had better RIVET it. If it must be WATER or GAS TIGHT, SOLDER it. If it is to be subjected to stress and must also be water or gas tight, then use BOTH fastening methods.

All you need allow for the seam is enough metal in each piece of stock to make the lap.

The GROOVED seam comes in handy for constructing such things as funnels, containers and tanks. Figure 1 shows the three steps in making such a grooved seam.

STEP (A) OPEN LOCKS — STEP (B) LOCKS HOOKED — STEP (C) SEAM GROOVED

Figure 1.—A grooved seam in galvanized iron.

First you form the edges of the pieces of metal to be joined into an open lock like that of (*A*). You usually do this in a bar folder, a machine you will learn to use.

This is the way to lay out the proper allowance and turn an open lock of the right size for a grooved seam.

Figure out the TOTAL ALLOWANCE for the seam. This allowance should be THREE TIMES the width of the seam.

Place ONE-HALF the total allowance on each edge where the seam is to be made.

Set the bar folder for the specified width of the seam MINUS ONE THICKNESS OF THE METAL.

Then you "hook" together the two open locks as in step (*B*) of figure 1. Now the seam is ready to be GROOVED as in step (*C*). You do this grooving with a hand groover, a riveting hammer and a sheet metal stake. Place the seam over a properly shaped stake. Then set the hand groover directly on the seam and strike it with the riveting hammer until the seam is locked or grooved. You'll get a better job if you have

a partner hold the metal on the stake for you so that he can pull the seam tight.

You must keep working the groover forward along the seam until the entire length of the seam is locked. Be careful as you do so, not to cut or mark the metal near the seam with the edges of the hand groover.

The STANDING seam is often used to join two sections or parts of an object.

The steps in making a standing seam are shown in figure 2. If the object has straight sides, the flanges may be turned on the bar folder. If it is cylindrical in shape you can turn them with a burring machine.

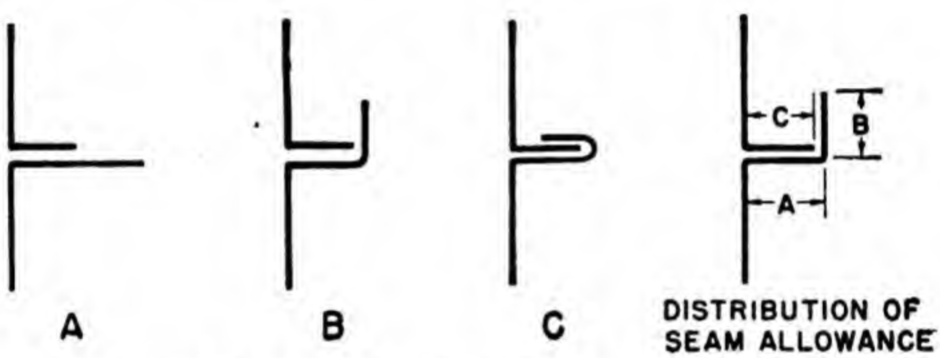


Figure 2.—A standing seam on galvanized iron.

Notice the distribution of the allowance for the seam. Two-thirds of it is in one piece and about one-third in the other. The lengths of sections *a* and *b* are equal while the length of *c* is one thickness of the metal LESS than *a*.

EDGES

To make a WIRE EDGE, wrap the metal around a piece of wire or a rod. You can bend the metal either by hand or on a bar folder. Allow an amount equal to two and one-half times the wire's diameter for the fold of metal which is to accommodate the wire.

Figure 3 shows a wire edge being made by hand. First you bend the metal partly over the wire with a mallet. Then the final shaping may be continued either

with the peen of a hammer, or with a wiring machine.

A wire edge like the one just described is one way to reinforce or stiffen the edges of a sheet metal object.

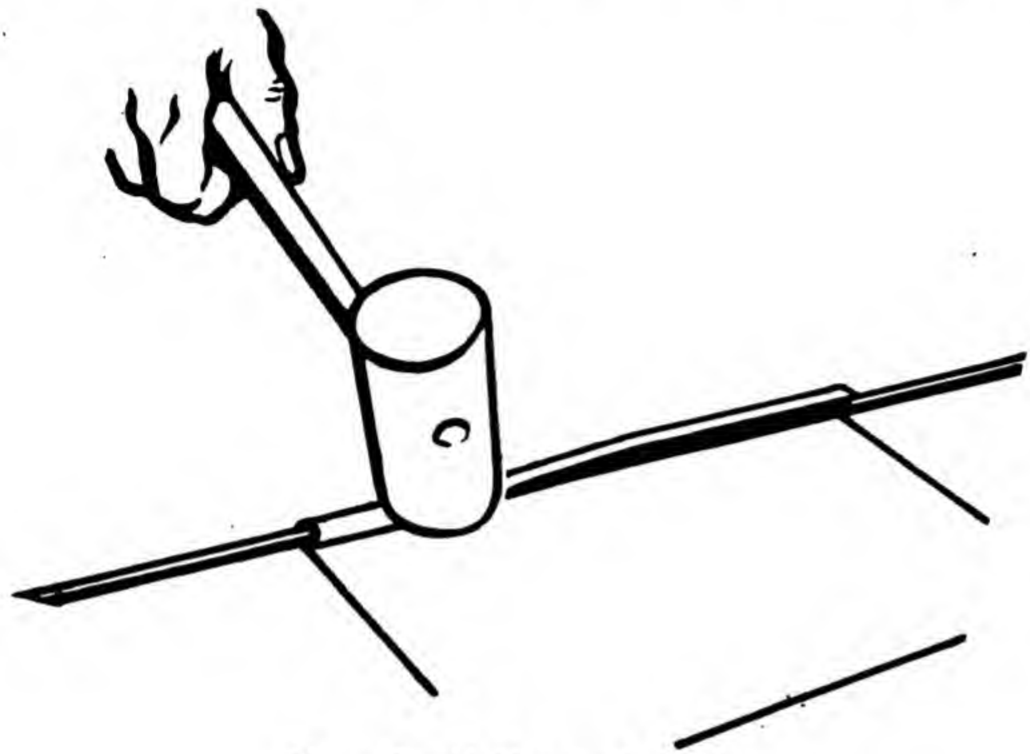


Figure 3.—Making a wire edge.

Another way is to make either a SINGLE or DOUBLE HEM in the metal like those in figure 4.

Figure 4.—A reinforcing edge.

You make a single hem by just turning the metal back upon itself once. For a double hem, fold the metal twice.

CUT IT UP

Most of the sheet metal used in aircraft is made from aluminum manufactured in aluminum mills in long, continuous strips. These strips average approx-

imately one and one-half city blocks in length and are formed on tables nearly a quarter of a mile long. Ten or twelve of these huge strips go into the structure of one of the Navy's giant transport airplanes.

Before they are shipped for use, these strips are cut into shorter lengths, usually not more than 24 feet long. On the job, these shorter strips are re-cut, bent, shaped, and molded to fit where they are needed.

They'll be used to fix up broken, and bullet-riddled parts when the damaged airplane returns to its base.

Your first step in repairing an airplane is to CUT THE SHEET METAL. There are a number of tools for cutting light gage metal and these are divided into three groups.

Hand shearing snips.
Manually (hand or foot) operated machines.
Power operated cutting machines.

SNIPS like those in figure 5 are, as you can see, a lot like scissors but considerably heavier. The two most common types of snips are STRAIGHT bladed ones and those with CURVED blades.

Straight snips cut metal along a straight line or along outside curves. Curved blade snips cut irregular edges.

You'll probably find AIRCRAFT SNIPS the most useful of your hand cutting tools. They can do a great variety of jobs.

All parts of aviation snips are interchangeable so that it is easy to replace worn or broken parts. The LEFT-HAND aircraft snips cut a curve to the left. RIGHT-HAND aircraft snips cut a curve to the right. A hook keeps the blades closed. Some aircraft snips have rubber grips to make them easier to use.

COMBINATION snips will shear along EITHER a straight or curved line. You can cut much smaller arcs and circles with them than with any other kind of snips. Look at the narrow blades with their sharp points. With such blades you can make INSIDE cuts—that is, cuts inside the outer edges of a piece of sheet metal.

If you want to cut a LONG SHEET without distorting

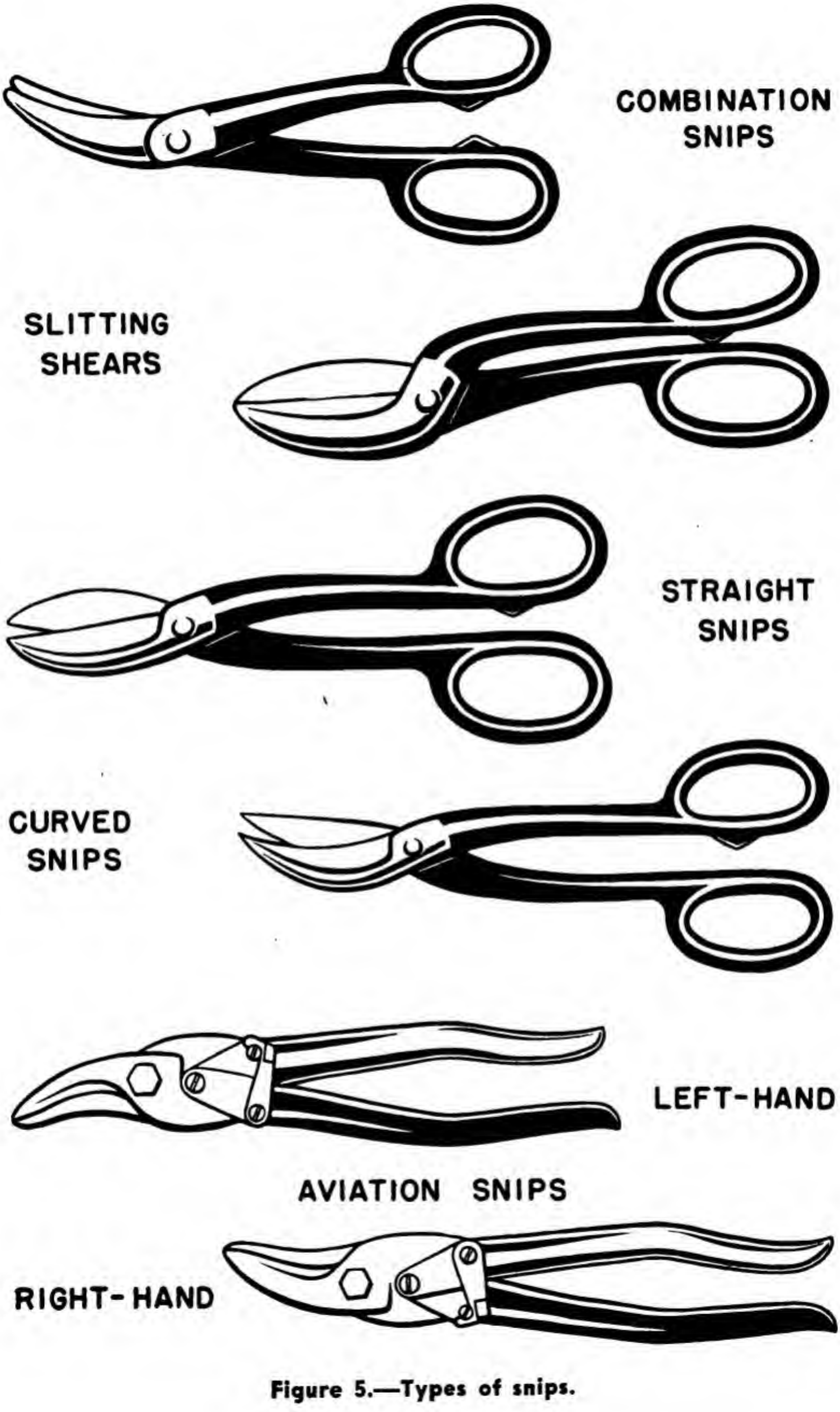


Figure 5.—Types of snips.

it, use the SLITTING SHEARS. The lower jaw of such shears is offset to permit the metal to pass. Thus the edges of the cut stay in close alinement and the two handle bows remain ABOVE the sheet and well away from the cut edges. The shape of the snips makes it possible for you always to be able to see clearly the scribed line along which you are cutting.

If hand pressure isn't enough to run your snips through the metal you're working with, it's time to STOP. This means that you must try not to force the

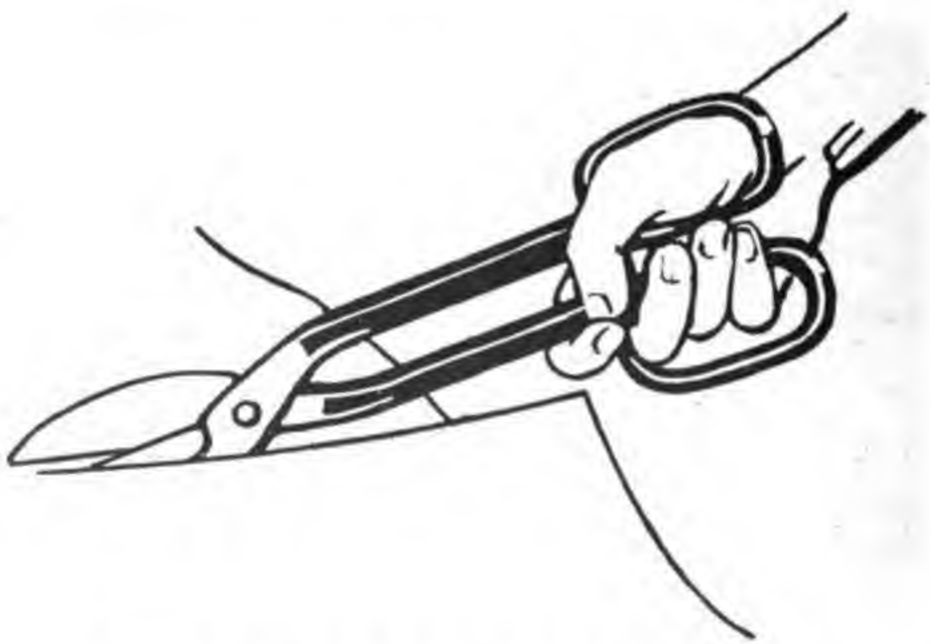


Figure 6.—The metal curls away from the snips.

snips to cut metal too heavy for them by striking them with some other implement.

Unlike the hacksaw, snips cut metal without removing any of the material. As the metal is sheared off, one part of it curls away to allow the snips to pass through the cut. The metal on the left-hand side curls up and that on the right-hand side curls down as in figure 6.

Cut on the LEFT-HAND side of a large sheet to allow the scrap, or narrow strip, to curl away.

Now come the MACHINES—either manually or power operated—WHICH CUT METAL FOR YOU.

For your big cutting jobs use the SQUARING SHEARS that you see in figure 7. It may be either foot or power operated. But don't try to cut metal heavier than 16 gage (.062 inch thick) on foot-power squaring shears. It will wreck your machine. To shear metal,

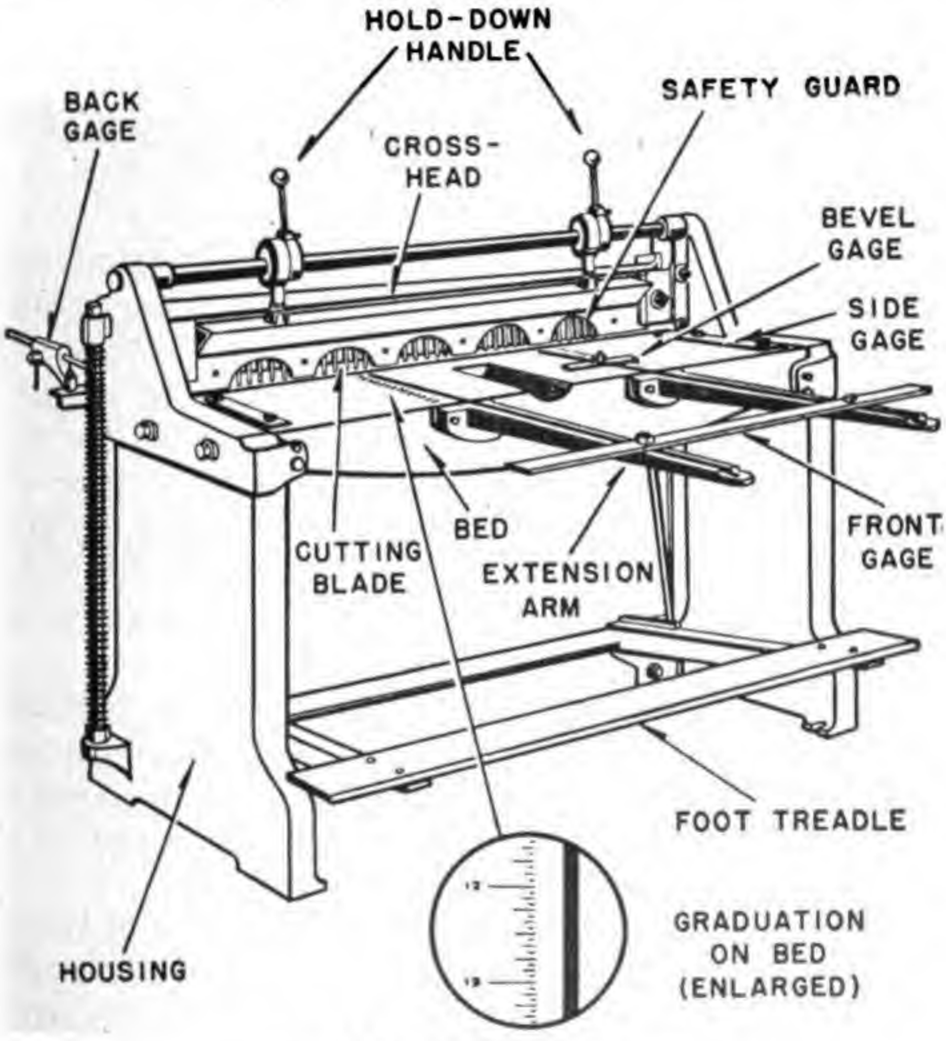


Figure 7.—Squaring shears.

you will usually insert it through the FRONT of the machine. However, if you want to cut a short section from a long sheet it is usually better to insert the stock from the REAR of the machine. Then the long end of the sheet is not in your way, and you have more freedom to operate the foot treadle.

Notice that the squaring shears are equipped with an ADJUSTABLE GAGE OR GUIDE BAR at the rear of the machine. You can set this guide bar for any length or width of cut desired. It is especially helpful in case a number of sections of the same size are to be sheared, because only one setting is required for all the material to be cut to that size.

The guide is easily adjusted. Simply move the bar forward or backward until it is the required distance from the cutting blade. If you insert the sheet from the rear of the machine, adjust the FRONT GAGE at the correct distance desired from the cutting blade, and fasten it to the bed of the machine.

If the piece is longer than the bed, the front gage must be connected to the extension, or bed gage, arms.

Slide guards are also provided on both ends of the bed of the machine to permit more accurate squaring of the stock. Always place the sheet so that one edge rests firmly against these side gages. Also at the same time make sure that the front or rear edge is squarely against the front or rear gages. Then when you apply the required force on the treadle, presto!—you've got a square cut.

NEVER BECOME CARELESS. One of these machines can clip off your fingers in no time at all. Keep your hands well back from the blade when you step on the treadle. Remember, the right way to do a job is the SAFE WAY.

But how about cutting large sheets along a curved line? Use the electric powered UNISHEAR, shown in figure 8. This machine can also be used for cutting along a straight line, but the squaring shears are more practical for this purpose. To use the unishear, place the metal between the cutters, turn on the switch, then guide the machine along the lines to be cut. The unishear can be used to cut black iron or galvanized iron up to 18 gage and aluminum up to 16 gage. The minimum radius which the machine will cut is one inch.

The BAR CUTTER shown in figure 9 is a hand operated

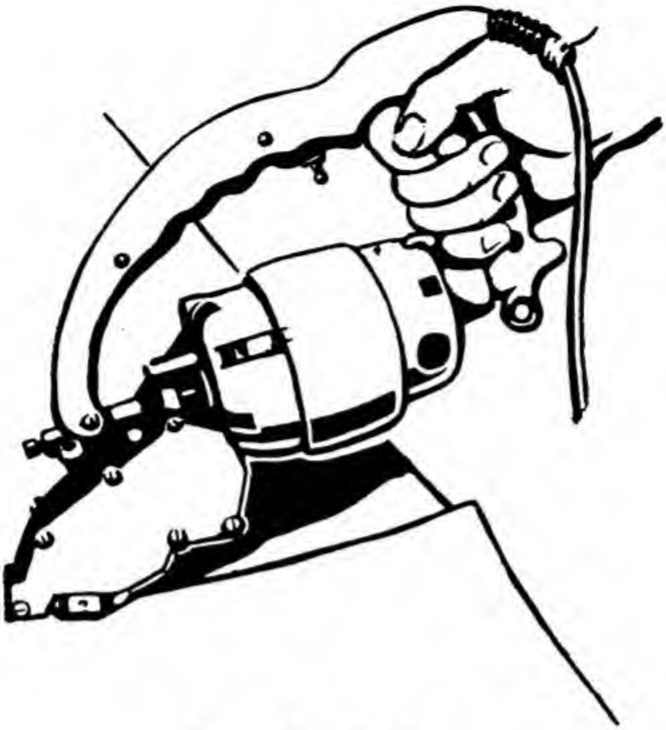


Figure 8.—Unishear.

machine for shearing soft metals. It has two steel blades which come together and slice off pieces of metal

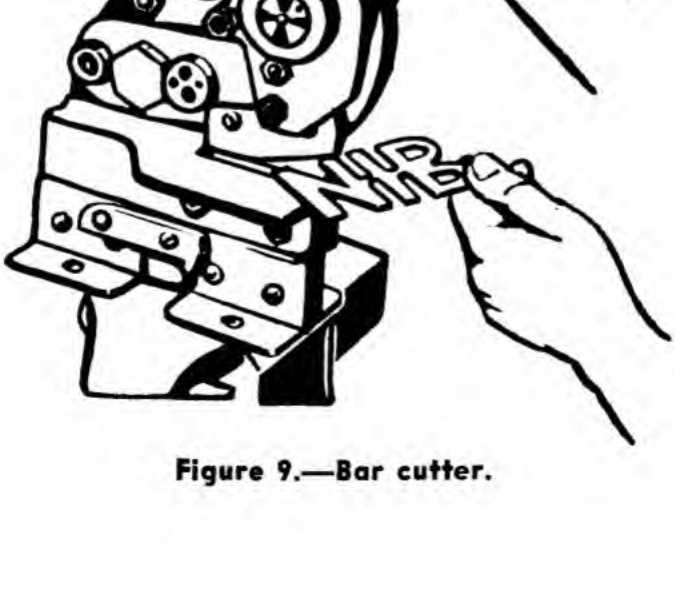


Figure 9.—Bar cutter.

the same way a hand snip does. A long handle or bar sticks up from the upper, moveable head to give you the necessary leverage to cut the metal.

Often you'll find you must make an opening in a sheet metal section. The equipment you have on hand will decide, of course, how you cut the opening.

The EASIEST and QUICKEST way to cut holes is to use a PUNCHING MACHINE. Such machines range in size and shape from the small, hand operated types like that of figure 10, to larger, power machines.

Such machines cut comparatively small holes. LARGE HOLES help to lighten metal sheets. You can cut them by using the combination scroll and circular shear, or the aircraft snip. OR, you can cut large holes with special hole-cutters which are mounted in a drill press.

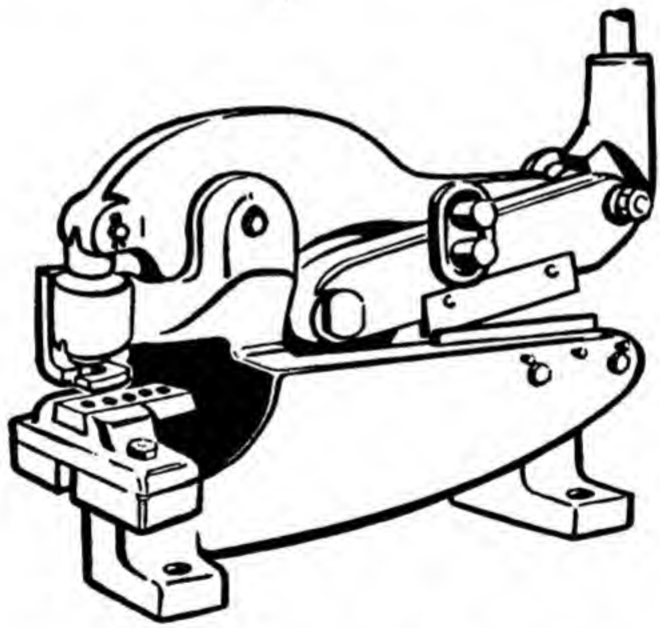
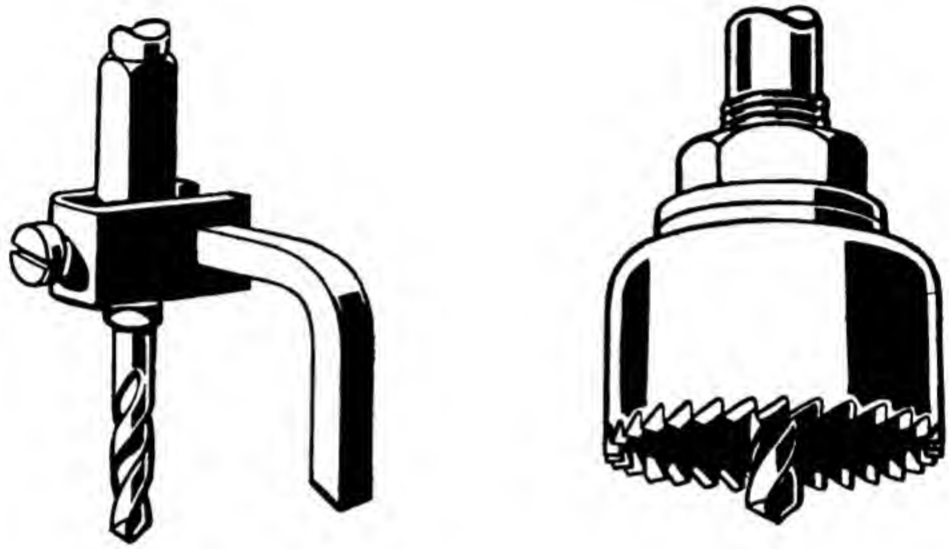


Figure 10.—Hand operated punch.

Look at figure 11. (*A*) shows a FLY-CUTTER and (*B*) shows a HOLE SAW, both of which are very efficient large hole cutters.

The fly cutter can be adjusted to cut various sizes of holes. Each hole saw cuts only ONE size hole but saws are available in a wide range of diameters.

Be sure you FASTEN SECURELY the metal to be cut when you use either of these devices. The metal should also be supported by a hardwood backing block. If you neglect to take these two precautions, you'll be sorry, because the metal is liable to be pulled from



(A) (B)

Figure 11.—Fly cutter and hole saw for large openings.

your hand. If that happens, YOU'LL BE VERY LUCKY NOT TO COME OFF WITH A BADLY CHEWED UP HAND, and the metal will look equally mangled.

HOW TO BEND IT BY HAND

There are more ways than one to bend sheet metal. Naturally, it is a good idea to know several ways to do the job. You may be called upon to do a rush job without the use of bending machines, or without complete equipment.

Even if machines are not available, you can make not only plain bends or folds in sheet metal, but also single and double hems, edges for grooved seams, and edges for wiring.

Such jobs can be done by using stakes, blocks of

wood, an angle iron, a vise, or the edge of a bench.

Forming sheet metal by hand or by using blocks or stakes CAN be a hard job unless you know how sheet metal reacts. You'll be smart to bend the metal only A LITTLE AT A TIME to avoid buckling or stretching. Be careful also to prevent kinks or marks from appearing on the surface of the work. If they do, you'll know it's because you used a metal hammer instead of a wooden mallet.

SHEET METAL STAKES

Stakes are the ANVILS of the sheet metal worker. By using hammers, mallets, grooving tools, etc., you can do all sorts of jobs on stakes. Tube forming, taper forming, flanging, seaming, and riveting are typical of such forming operations. As a skilled sheet metal worker, you will resort to a stake whenever a suitable machine is not available or when the available machine is not adapted to the job at hand. Figure 12 shows some common types of stakes.

The CONDUCTOR STAKE which has two cylindrical horns of different diameters, is used for forming and seaming pieces or parts of pipes or other cylindrical objects.

The BEAKHORN STAKE is a general purpose stake, used for riveting, or for shaping round or flat surface work, straight surface bending, corner seam closing, and so on. It has a round, tapered horn on one end and a square, tapered horn on the other end.

The HOLLOW MANDREL STAKE is useful for pipe forming and seaming. It also has a handy, square surfaced working end. The full length tee slot and clamping bar give you great leeway in fastening it to the bench.

The HATCHET STAKE is a sharp, straight stake with a hardened edge. It is used for making straight sharp bends, folding and bending edges.

The SQUARE STAKE is a general utility stake with a

flat, square anvil head which may be used for many bending purposes. It comes in three sizes—large, common and small. The beveled edge has an offset shank so that large work will clear the bench. The coppersmith's stake has one end rounded. All except the small squares have hardened steel heads.

The BLOWHORN STAKE has two horns of different

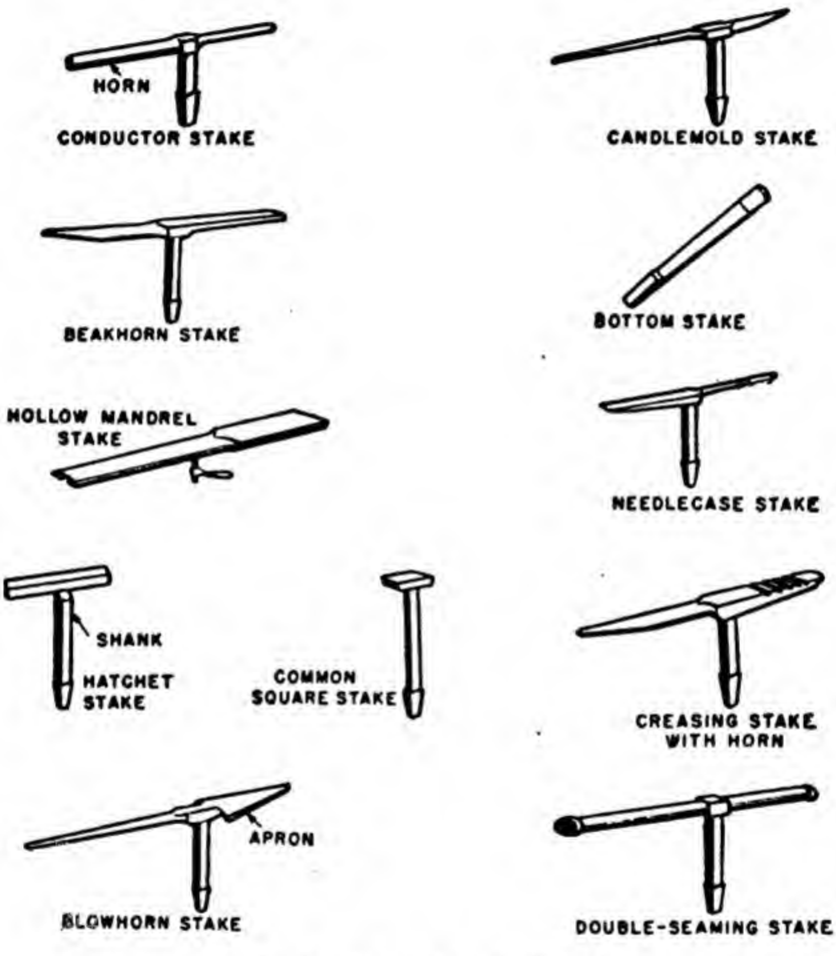


Figure 12.—Sheet metal stakes.

tapers. The apron end is used for shaping abrupt tapers while the slender tapered end is used for slightly tapered jobs.

The CANDLEMOLD STAKE has a round, tapering general purpose horn and a slender horn for tube forming or reshaping.

The ROUNDHEAD STAKE has a head with rounded surface for general use.

The BOTTOM STAKE is used for burring or flanging circular bottoms. It has a hardened tool steel edge.

The NEEDLE CASE STAKE has a round, slender horn for small tubes and a heavier horn for rectangular cross sections.

The CREASING STAKE WITH HORN has one horn like that on a common creasing stake, plus another for general use which is round and tapered.

A DOUBLE SEAMING STAKE is useful for laying down the bottom seams of vessels.

BENDING BY HAND

The next few illustrations cover the basic principles of bending and the types of stakes used in each case.

To bend a piece of sheet metal to form a CYLINDRICAL object like a stove pipe, use the HOLLOW MANDREL

(A) (B)

Figure 13.—Bending metal on a hollow mandrel stake.

STAKE. Place one end of the metal over the stake, holding it in place with your left hand. Then with your right hand start the bend with a mallet as shown in figure 13(*A*). Next, hold the metal on the stake with your right hand and bend it around the stake with your left hand as illustrated in figure 13(*B*). Move the metal slightly to the right and bend it down again.

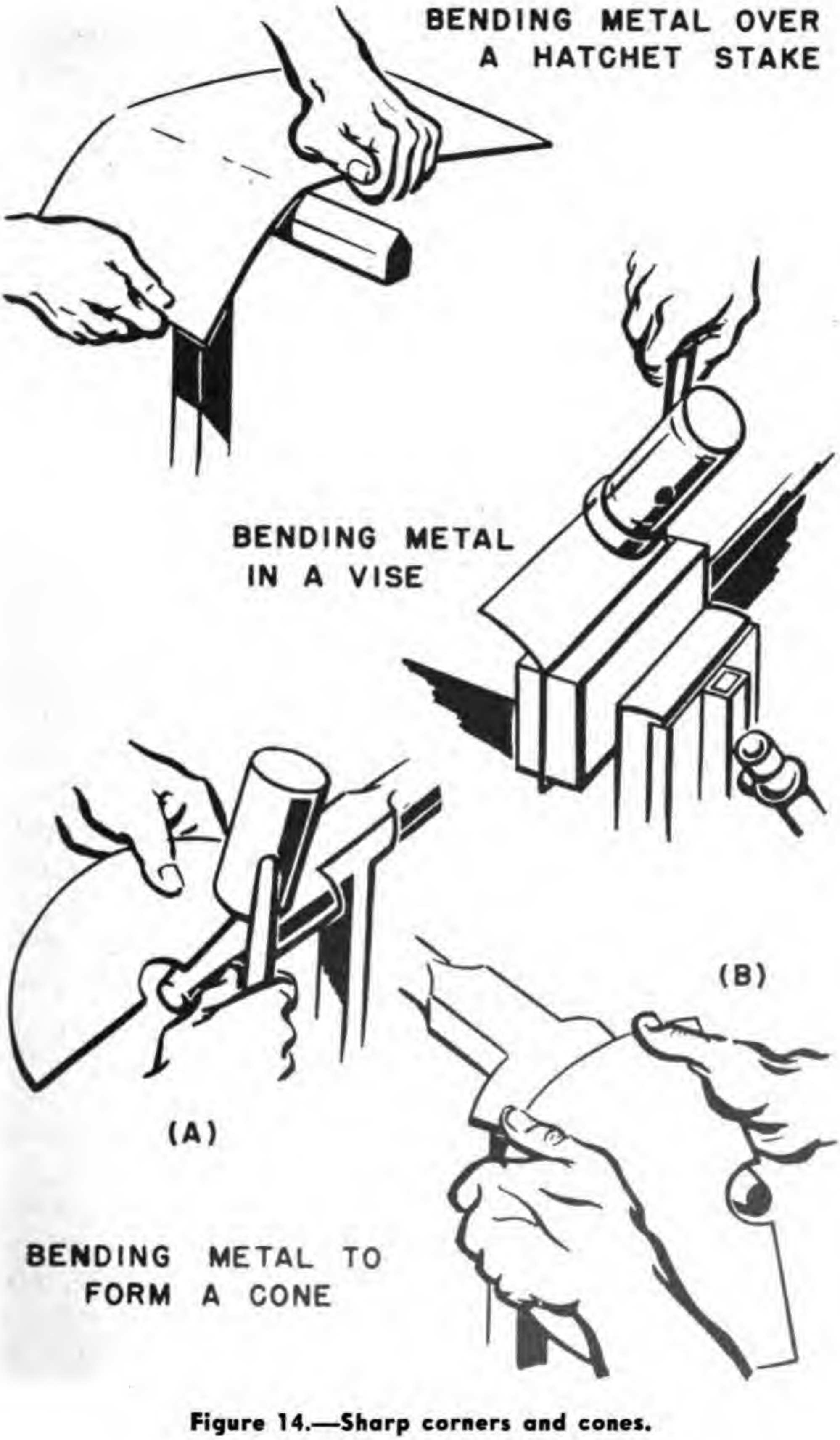


Figure 14.—Sharp corners and cones.

Continue this process of bending and moving the metal until you have worked the sheet all around the stake. When you wish to make a SMALL cylindrical object, use the CONDUCTOR STAKE or a PIECE OF PIPE instead of the hollow mandrel stake.

If you are without a bending machine and have to make a sharp, straight bend on a light piece of sheet metal, use a HATCHET STAKE and bear down as shown in figure 14. The line at which you wish to bend the stock should be placed to coincide with the edge of the stake. Hold the material firmly with one hand and press downward with the other hand on the part of the metal that extends over the stake. Then complete the bend by hammering the metal with a mallet on the square horn of the BEAKHORN STAKE.

When you wish to bend a piece of metal into a CONICAL job to look like an overgrown ice cream cone, use the BLOWHORN STAKE.

Start the bend with a mallet as shown in figure 14(*A*). Then hold the bent edge over the stake with your right hand and bend the metal around the stake with your left hand, as illustrated in (*B*).

Next, move the metal slightly so as to bring a straight portion onto the stake. Then bend again. Continue moving the metal over the stake as each portion is bent until the entire piece is properly shaped. To avoid kinks while forming, bend the metal around the stake with a rolling motion.

You can do a very neat job if you take a little time and are careful.

Another simple way of bending small pieces of metal is to use the VISE shown in figure 14.

Place the stock between two wooden blocks, insert in the vise as illustrated, and hammer the upper section with a mallet until the correct bend is made. To make a round bend with a definite radius, round the edge of the inside block so that the radius is equal to the required radius of the bend.

A ball-peen hammer or any other type of metal ham-

mer has a tendency to scratch and mar the surface of aluminum metal. REACH FOR A WOODEN MALLET INSTEAD!

As an extra precaution, it is a good idea to place masking tape over either the face of the mallet or the metal at the bend line.

In other cases when you wish to bend a piece of metal without a machine, you may do so by placing it on a CLEAN BENCH TOP, or else between two wooden or metal blocks held together with clamps. In either case your procedure is much the same. Mark the posi-

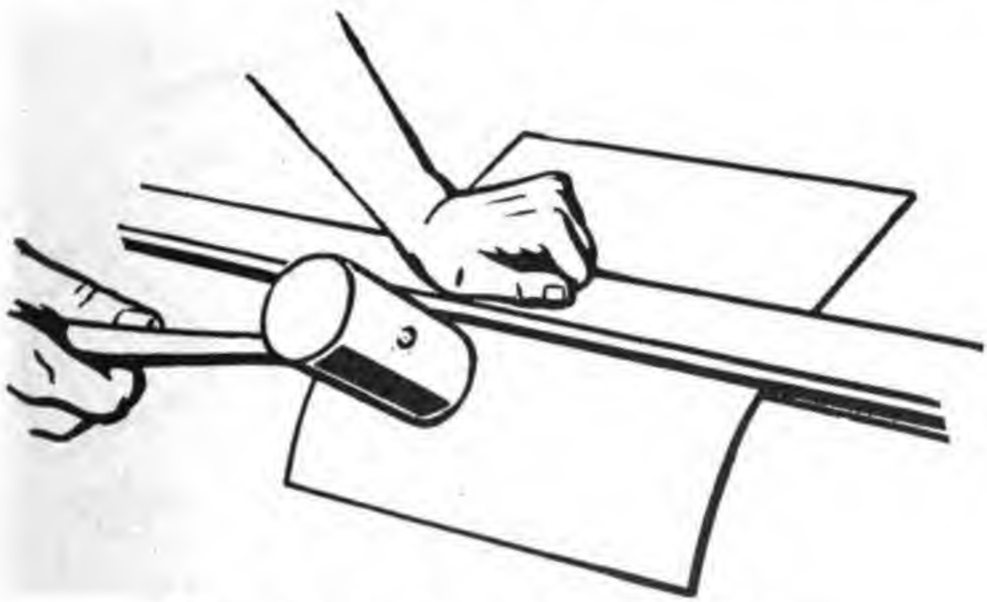


Figure 15.—Bending metal over a bench top.

tion of the bend on the stock. Place the line of the bend over the edge of the bench top. If you bend the metal between two blocks, place an angle iron directly over the bend line. Then secure the two blocks with C clamps. In either case, you make the bend by hammering with a wooden mallet as in figure 15. If you use a bench top, be sure that its edge is smooth and square.

BENDING BY MACHINE

One of the most common operations in sheet metal work is THE FOLDING OF METAL. To fold a hem or

turn a lock, you must have some way to hold the metal firmly so that the desired shape can be made where it is needed.

For this purpose, two types of machines are used. One, called a FOLDER, LIMITS THE WIDTH OF THE FOLD. The other, known as a BRAKE, DOES NOT limit the width of the fold.

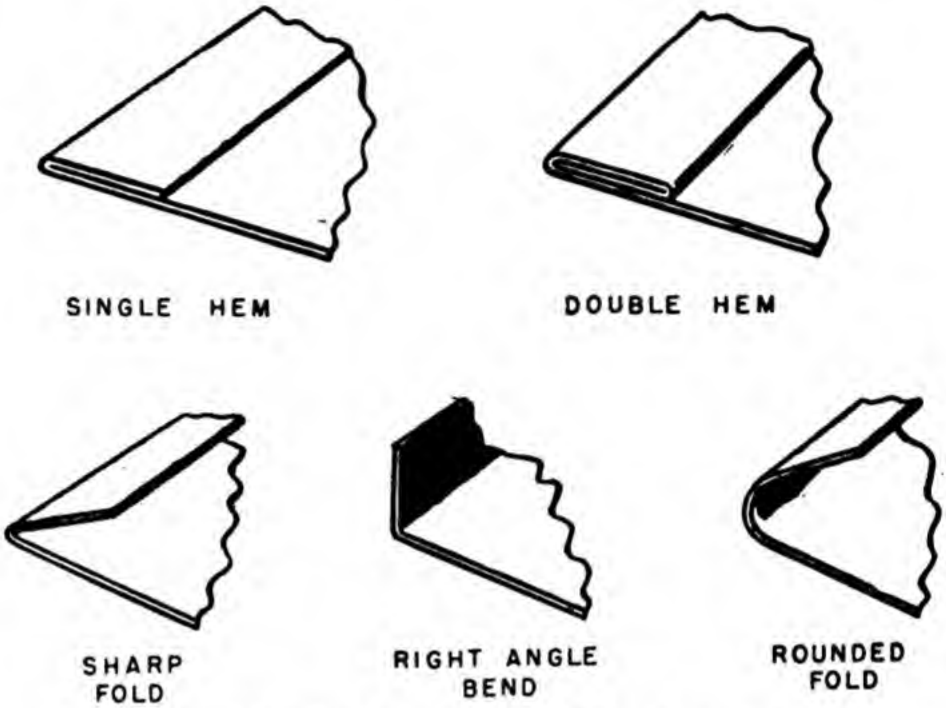


Figure 16.—You can make these folds on a bar folder.

Figure 16 shows the various types of folds which can be made on the BAR FOLDER shown in figure 17. The bar folder is a machine which bends or folds the edge of a piece of sheet metal to form a FLANGE, a CLOSED LOCK for a hem, or a CURVED FLANGE for a wire edge. It has two adjustments. One regulates the width of the flange or hem. The other regulates the sharpness or roundness of the fold.

Bar folders come in various sizes, depending on the LENGTH and also the GAGE of the sheet they are designed to fold. The working lengths range from 20 to 40 inches. Most bar folders will handle soft steel sheet

up to maximum of 22 gage. The maximum depth of a fold is one inch. These folders are equipped with two positive stops—one for 45° and the other for 90° bends. Then there is a third stop by which the bar folder can be adjusted to obtain a bend of any desired angle. Use the stops for accurate bending and for duplicating a number of identical bends.

TRY A FOLD

A bar folder is easy to use. First, set the gage adjusting thumb screw in figure 17 to the specified width of

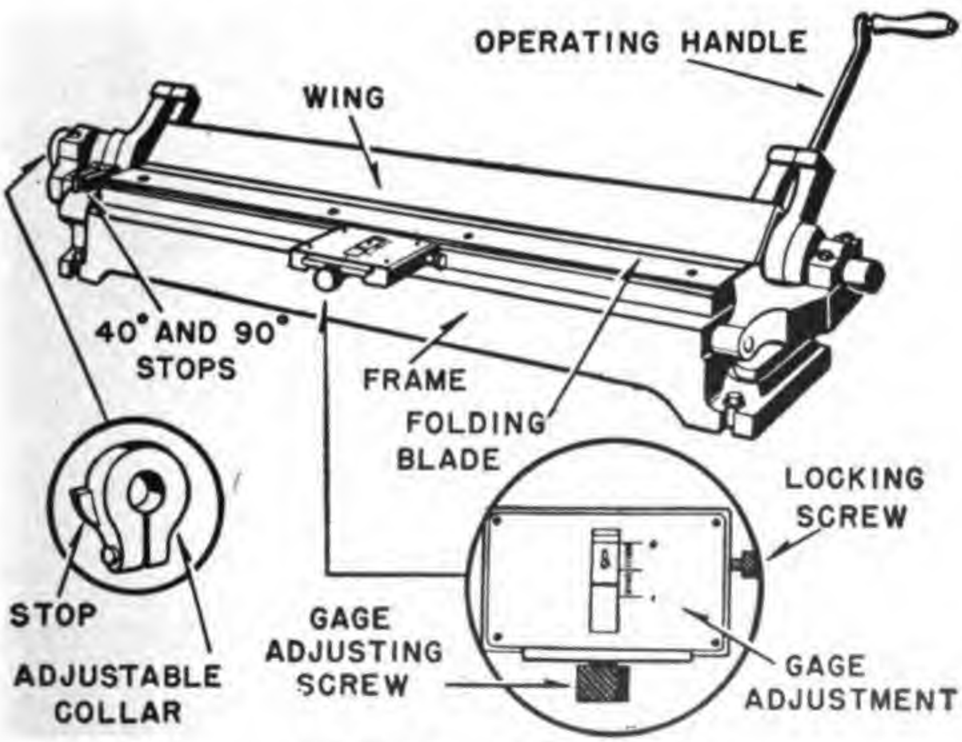


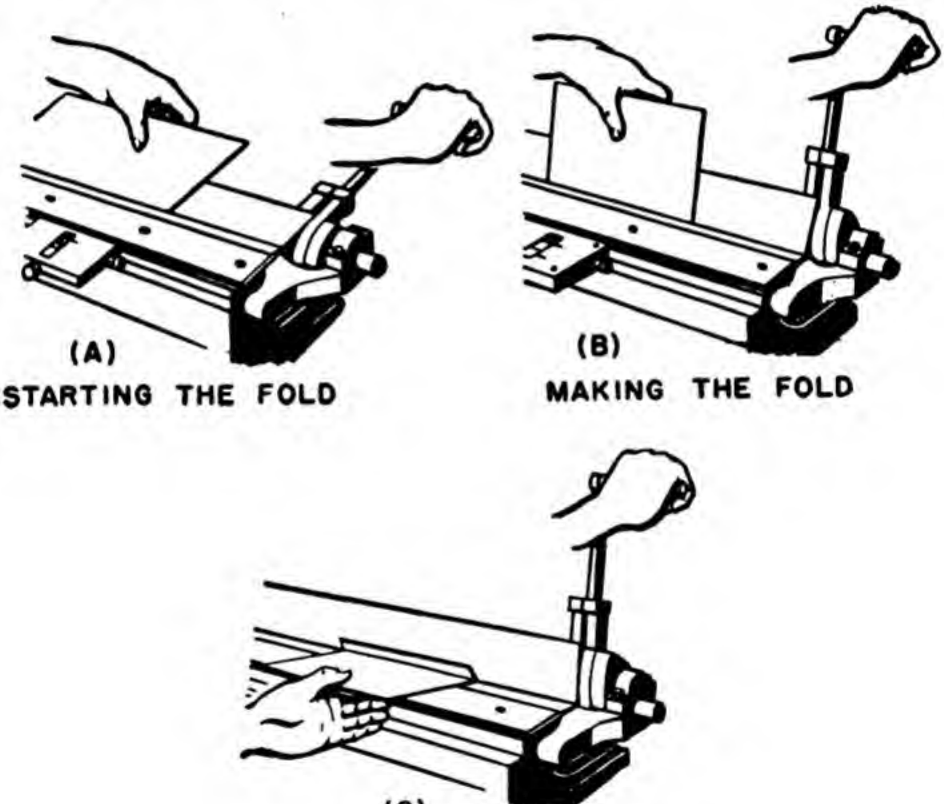
Figure 17.—A bar folder.

the fold. Turn the adjusting lever at the back of the machine to suit the bend you want to make. Before you begin a job, better check the operation of the machine by making trial folds on some scrap stock. If they turn out OK, you're ready to go.

Insert the metal as far as it will go under the folding blade. Grab the metal and hold it firmly in place

with one hand. With the other hand, grasp the operating handle and pull forward until the desired fold is made. The distance you move the handle decides the angle of the fold. The STOPS mentioned govern this distance and thus DETERMINE THE AMOUNT OF BEND.

Figure 18, *A* and *B*, shows the steps you take in bending a piece of sheet metal. An extra step is necessary if you want to flatten down a hem. First make an angle bend. Then remove the metal and place the folded section on the flat bed of the folder as in step *C*. Then squeeze the hem flat.



(A) STARTING THE FOLD

(B) MAKING THE FOLD

(C) FLATTENING THE HEM

Figure 18.—Steps in making bends and folding hems.

Use a SINGLE hem for a SMOOTH EDGE on a sheet. When you want to conceal ALL roughness and give the stock additional stiffness, use a DOUBLE HEM.

The CORNICE BRAKE is a machine for bending LARGER SHEETS of metal and for folding edges larger than one inch. Also hand operated, this machine is used in much

the same manner as the bar folder. However, in aircraft construction and repair the cornice brake machine is limited to making simple bends.

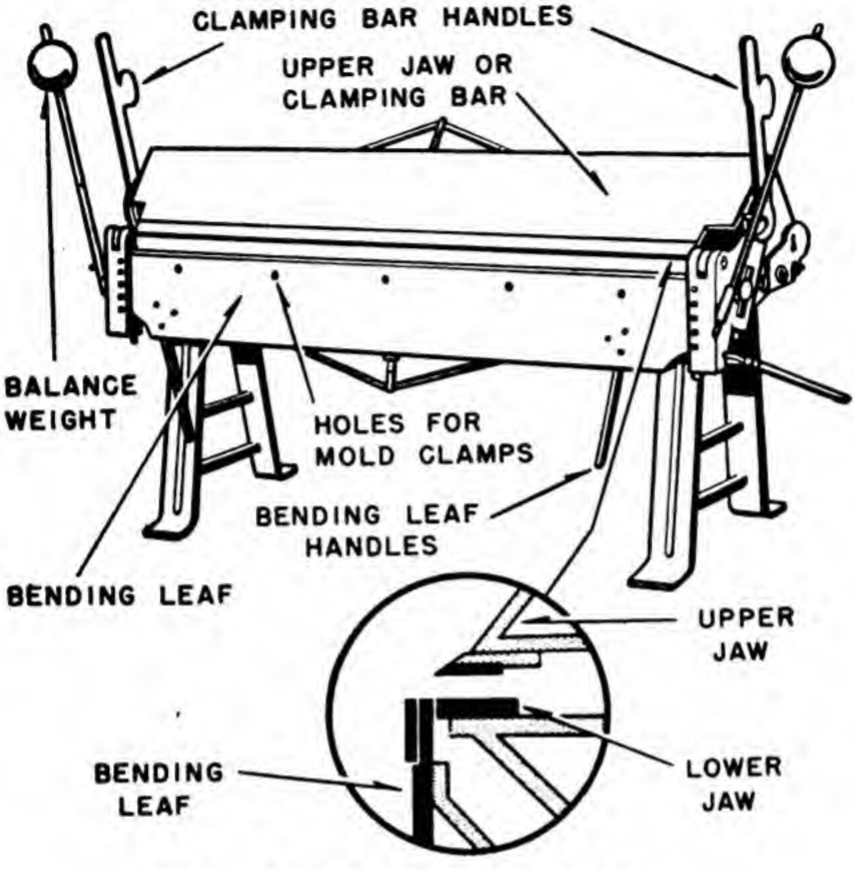


Figure 19.—Cornice brake machine.

To operate the cornice brake, insert the sheet between the upper clamping jaw and the lower jaw and clamp it in place by the leaf handle indicated in figure 19, to produce the bend. The distance you move the wing governs the angle of the bend. Notice that two balancing arms with adjustable weights are attached to the bending leaf to make the braking easier.

The upper jaw can be moved forward or backward to regulate the radius of the bend. When a sharp bend is required you should adjust the upper jaw so that its edge extends a distance equal to the metal's thickness from the edge of the lower jaw. When you increase this distance, you increase the radius of the bend.

Either one of the clamping bar handles which move independently of each other, will clamp or release the work, making it possible for one man to operate the brake.

Never bend wire, rod, band iron, or seamed pieces on the cornice brake, since this would ruin the upper jaw blade and the bending leaf blade, as well as disturb the adjustment of the machine. Sizes of cornice brakes range from 3 to 12 feet in length and from 22 to 12 gage in capacity.

A BOX AND PAN brake like that in figure 20 is useful when your work requires jaws of various widths. It is an adaptation of the cornice brake.

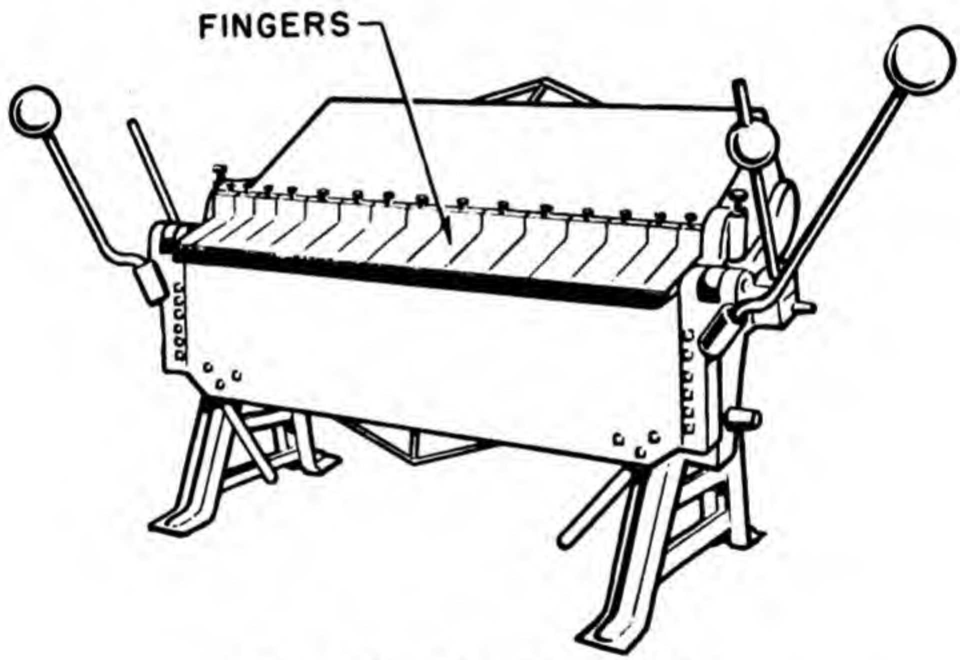


Figure 20.—Box and pan brake.

The jaws must be perfectly alined before you make a bend. You can adjust their width by removing and arranging the fingers. Be very careful when you use a box and pan brake to AVOID DIGGING THE CORNERS OF THE JAWS INTO THE BENDING LEAF OF THE BRAKE.

Before bending any work which must have an accurate bend radius and a definite leg length, you should check the setting of the brake with a piece of scrap.

The point in relation to the jaws at which you place the metal in the brake, decides whether or not the leg length of the piece is correct.

If you neglect to check the machine and your work is incorrectly bent, you waste not only the time and work you spent in computing the bend allowance, but

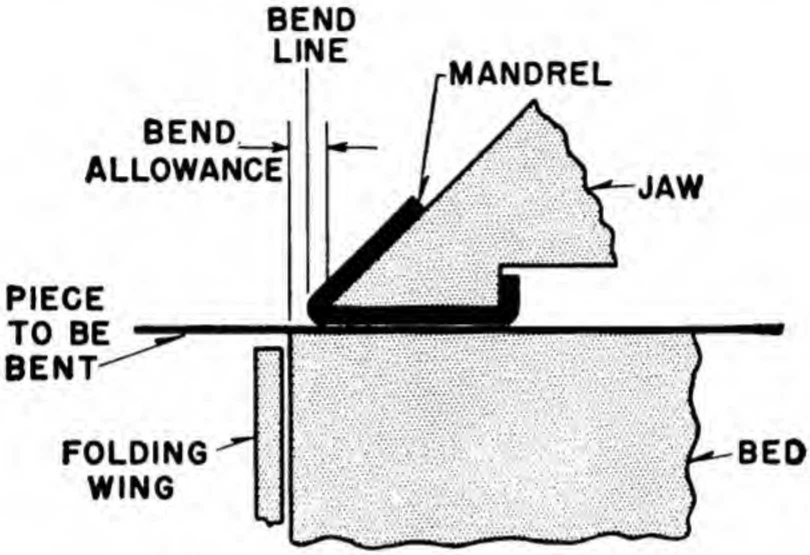


Figure 21.—Inserting the metal.

also the metal itself. And once a metal is bent it is almost impossible to flatten it out and re-bend it. This is ESPECIALLY true of heat treated aluminum alloys.

Most brakes come equipped with RADIUS BARS for adjusting the brake to the correct bend radius. If these bars are not available, you can use sheet metal of various thicknesses to build up the upper jaw until its curve is large enough to give the desired bend radius.

In this case, you have to experiment until by trial and error you achieve the proper curve of the upper jaw. ALWAYS test for the proper bend radius with scrap metal before you go ahead on the job at hand.

Figure 21 shows one way to attach a MANDREL to the brake so that when the upper jaw is raised the mandrel won't slip down.

After computing and marking off the bend allow-

ance, insert the metal into the brake so that the bend line comes directly under the edge of the upper jaw.

ROTARY MACHINES

Rotary machines are handy pieces of sheet metal equipment to have around for a number of reasons. They can be used for BURRING, TURNING, WIRING, elbow and collar EDGING, and FLANGING.

A BURRING machine is a rotary machine on which a set of BURRING ROLLS have been mounted as in figure 22.

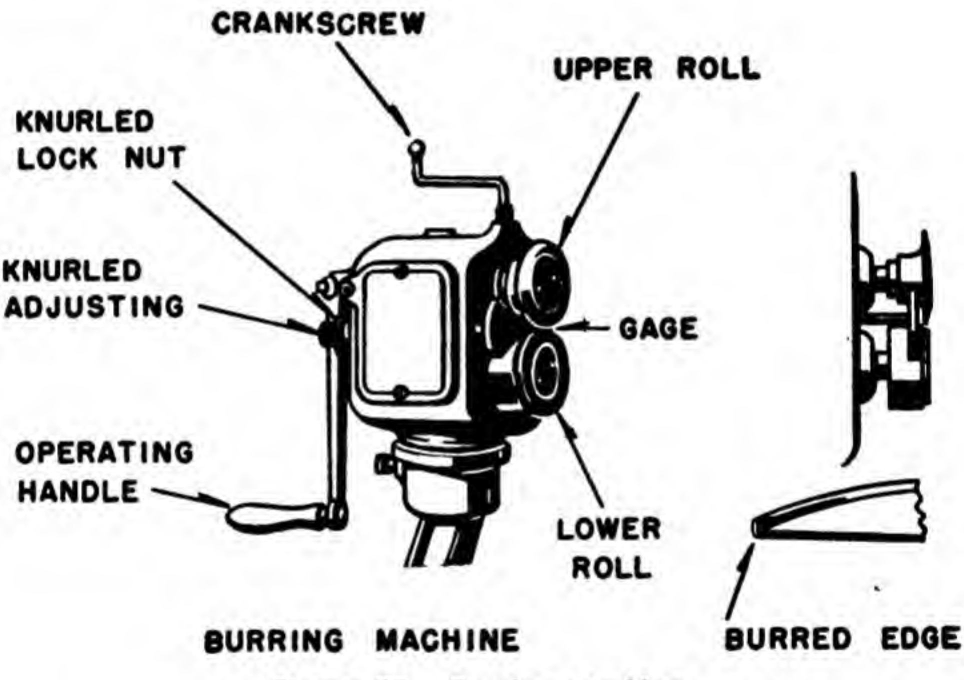


Figure 22.—Burring machine.

Such an attachment is used to turn a uniform EDGE or FLANGE on metal cylinders or disks when you are making a double seam, a standing seam or a snap bottom. Such an edge is shown in figure 22.

BURRING IS HARD TO DO. It is perhaps the most difficult job on a rotary machine. It takes a lot of practice and patience to become adept at it.

Suppose you want to turn an edge on a disk for a snap bottom. Here is what you do.

Adjust and aline the rolls so that the top roll fits down over the shoulder of the lower roll as in figure 22. The distance between inside face of the top roll and the shoulder on the lower roll should equal the thickness of your work.

Set the gage. For this disk, you would want to set the gage for a scant $\frac{1}{8}$ inch from the inside of the top roll's back face.

Place the disk so that its face rests on the two

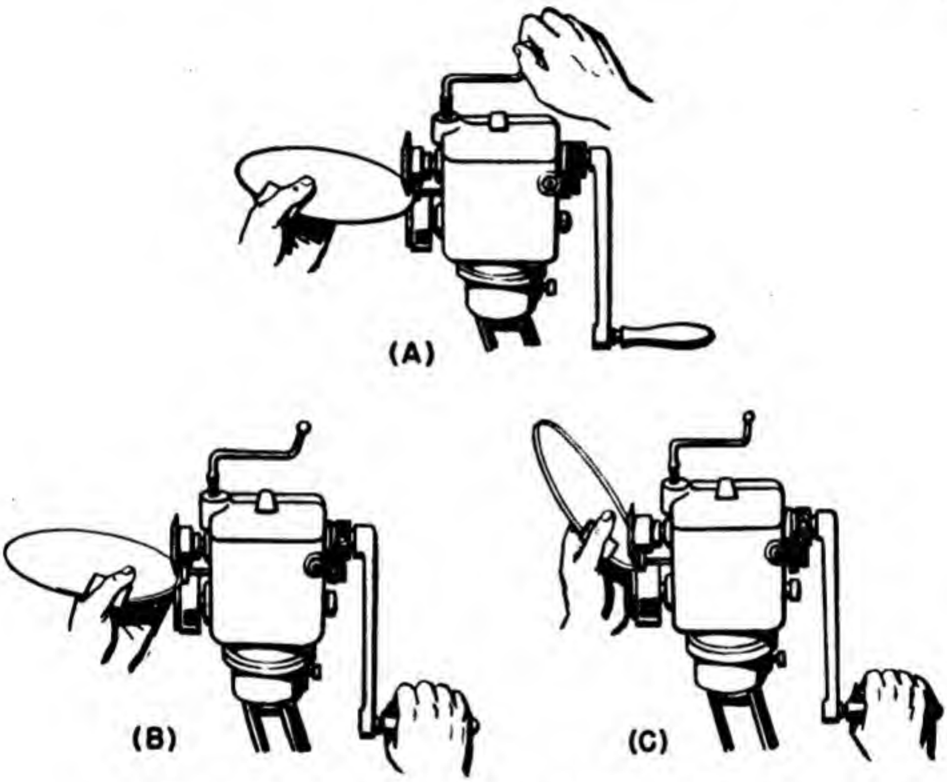


Figure 23.—Steps in making a burred edge.

edges of the lower roll. Its edge should be against the gage as in figure 23 (*A*). Now lower the top roll until it JUST GRIPS the metal disk.

Brace one hand by resting the palm against the gage while you grip the disk between thumb and index finger.

With the other hand, turn the crank slowly. As you turn, hold the disk firmly against the guide by applying pressure just IN FRONT of the rolls. (Fig.

23 (*B*)) You must make the "track" during the first revolution of the disk. And DON'T LET THE DISK JUMP OUT OF THE ROLLS.

After the first revolution, increase the speed at which you turn the crank. At the same time, gradually raise the disk as in figure 23 (*C*) until the burr is turned.

A TURNING machine is a rotary machine on which a set of TURNING ROLLS have been mounted. You will use it to form a curved flange, the first step in making a wire edge on a cylindrical object. You can also use

Figure 24.—A curved flange and a bead.

the turning attachment for turning a bead. Figure 24 shows results of these two operations. Figure 25 is a drawing of a turning machine. Compare the turning rolls at extreme right with the burring rolls in figure 22.

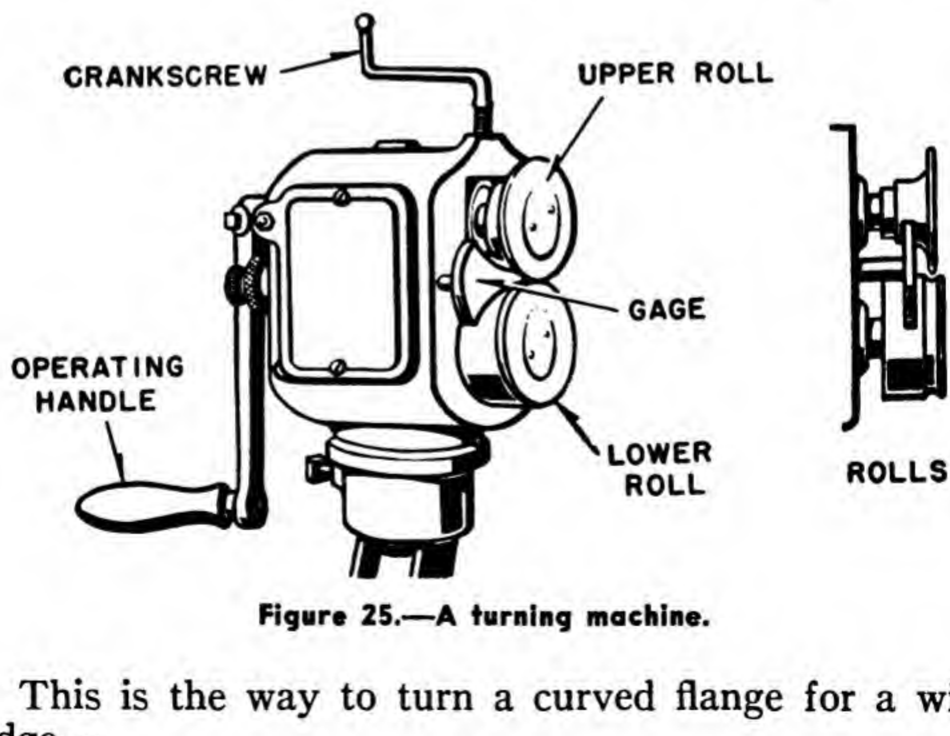


Figure 25.—A turning machine.

This is the way to turn a curved flange for a wire edge—

Aline the rolls so the top roll is centered in the groove of the lower roll.

Set the gage according to the diameter of the wire. You'll have to determine this adjustment by trial and error with a piece of scrap stock of the same gage as the stock on which you are to work.

Next place the metal piece between the rolls and press it against the gage.

With your work in place, lower the upper roll by turning the small crank screw until the top roll just grips the metal. Now turn the crank. SLOWLY. Hold

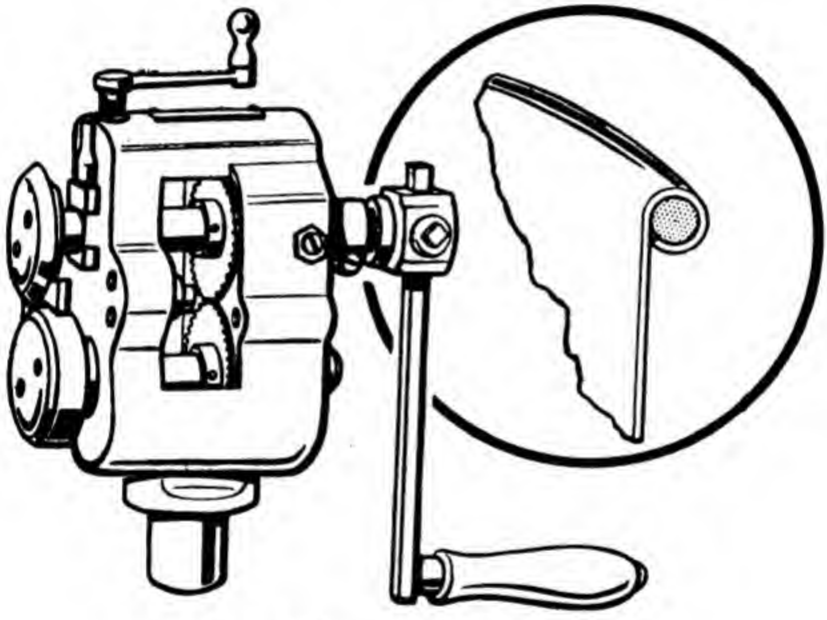


Figure 26.—A wiring machine.

the metal so that it feeds into the rolls but still keeps clear of the gage. Be very careful to make the first revolution so that the "track" is right and DON'T let the metal jump the rolls.

After the first revolution, increase the speed of the crank as you gradually raise the metal until it is touching the outer face of the top roll. Finally, remove the stock by raising the top roll.

A WIRING MACHINE is usually used to complete a wire edge (started in the turning machine). It turns

the edge AROUND THE WIRE. It is a rotary machine with a set of wiring rolls mounted upon it and can be used on either a STRAIGHT or CURVED edge. Figure 26 shows a wiring machine while figure 27 shows the steps taken in completing a wire edge on this machine.

Adjust the rolls so that the top roll is directly above the point on the lower roll where the beveled and flat surface meet as in (*A*) of figure 27.

Next set the guide to the positions shown in (*B*). Now bring down the top roll so that it will turn the edge around the wire as in (*C*).

Finally, take the stock from your machine by raising the top roll.

Say you want to stiffen either a flat or curved surface by turning a bead on it. Use a BEADING MACHINE —that is, a rotary machine with a set of BEADING ROLLS mounted upon it. These rolls will turn either "OGEE" or SINGLE beads. Figure 28 shows the beading rolls.

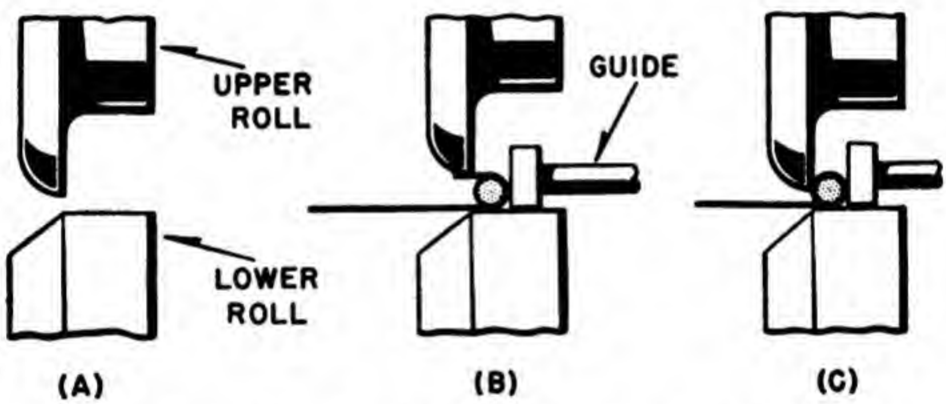


Figure 27.—Turning an edge around a wire.

To operate the beading machine, first aline the rolls and then set the gage so the bead will be turned at the correct spot in the metal.

Then insert your work between the rolls and turn the crank screw to lower the top roll until it makes a small impression on the metal.

Now run the metal completely through the ma-

chine once VERY SLOWLY so the "track" will be correct. Keep the stock firmly against the guide.

Next readjust the crank screw so as to increase slightly the pressure of the top roll against the metal. Then run the metal through again.

Continue tightening the crank screw slightly after

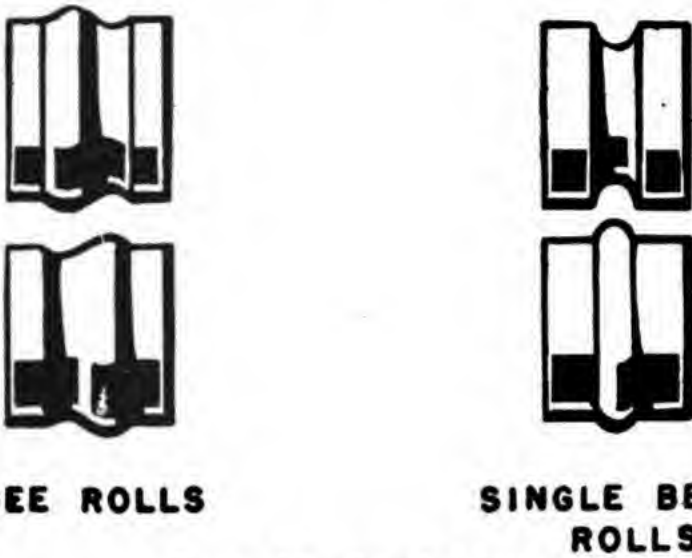


Figure 28.—Beading rolls.

each revolution until the bead reaches the right depth.

DON'T try to form a bead in one operation. You'll overstrain the metal. And don't attempt to force SEAMS through the rolls without raising the top roll. You have set the machine for a given thickness of metal. It won't take metal any thicker.

ROLLING SHEET METAL

As an Aviation Metalsmith you must be able to understand and cope with the basic machines for rolling metal which you'll find in a sheet metal shop.

The SLIP-ROLL FORMING MACHINE in figure 29 is the one you would use to form CYLINDRICAL SHAPES like pipes, stacks and tanks. It also will form TAPERED cylindrical shapes like pails, reducers, and air scoops. Then there are special aircraft shapes like the fuselage

skin and leading edges of a wing which can also be formed on a slip-roll forming machine.

This machine is composed of three rolls. Two of these rolls are geared to feed the sheet while the third serves as an idler to shape the metal as the stock comes through. Notice that one end of the top roll may be swung free of its gearing to permit you to remove a formed object easily.

You should oil the machine at regular intervals.

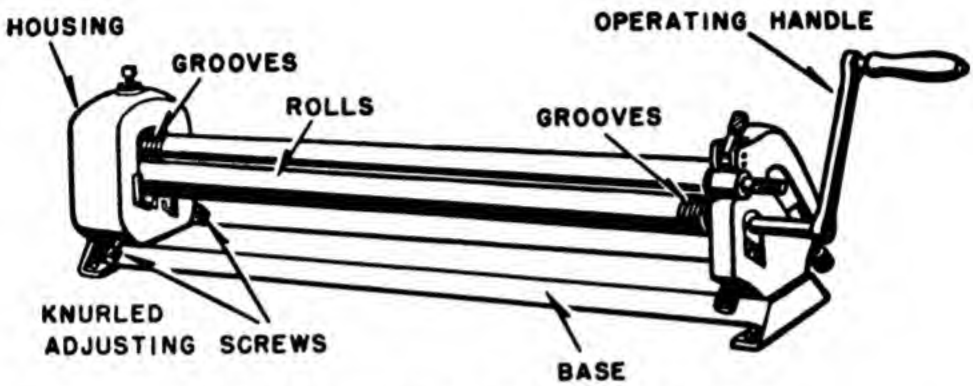


Figure 29.—Slip-roll forming machine.

It will take PLENTY OF EXPERIENCE before you can make well-formed shapes with this machine. It's impossible to say just how far the rolls should be separated to make the necessary curvature. That's something you must figure out by experimenting. The fewer "passes" you make to shape the stock, however, the better job you'll do. Tapered jobs are harder, of course, than plain cylindrical jobs.

TRY ONE

Lock the top roll into position. Then adjust the lower front roll by means of the knurled thumb screws at either end of the machine, until the two rolls grip the metal. Be sure the screws are turned an equal amount, otherwise the material will not roll evenly.

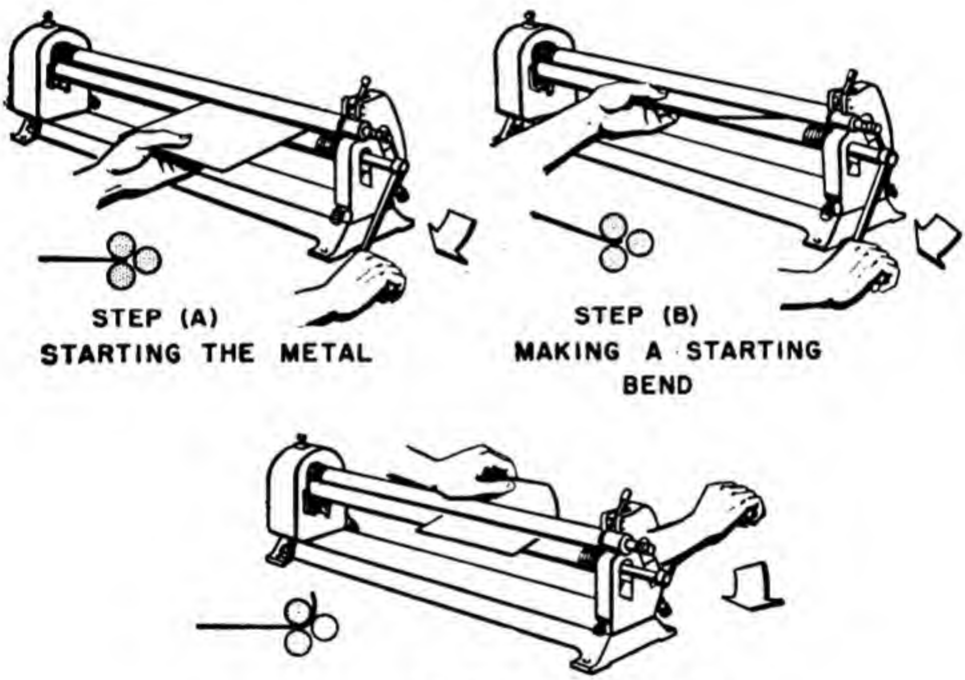
Insert the metal sheet between the rolls from the

front of the machine and start the metal by turning the handle as in (*A*) of figure 30.

After the edge of the stock is caught, raise the sheet with one hand to make the starting bend as in (*B*).

Now roll the sheet through the machine as in (*C*). If the curvature isn't right, roll the sheet backwards to its starting position. Then readjust the rear roll and run the sheet through again. Keep on trying until you get it right.

When it IS right, take the sheet out by raising the top roll.



STEP (A) STARTING THE METAL

STEP (B) MAKING A STARTING BEND

STEP (C) FORMING THE BEND

Figure 30.—Rolling a cylindrical form.

NOW, TRY A TAPERED SHAPE.

Set the rear roll so that the rolls are closer together at one end than they are at the other as in figure 31.

Then put the sheet into the machine. As you turn the handle, HOLD THE SHEET BACK so that the lines aa′, bb′, and cc′ pass THROUGH THE CENTER OF THE UPPER ROLL as in figure 31.

Another way to do this is to roll the sheet partly through the machine and then PULL BACK the short end

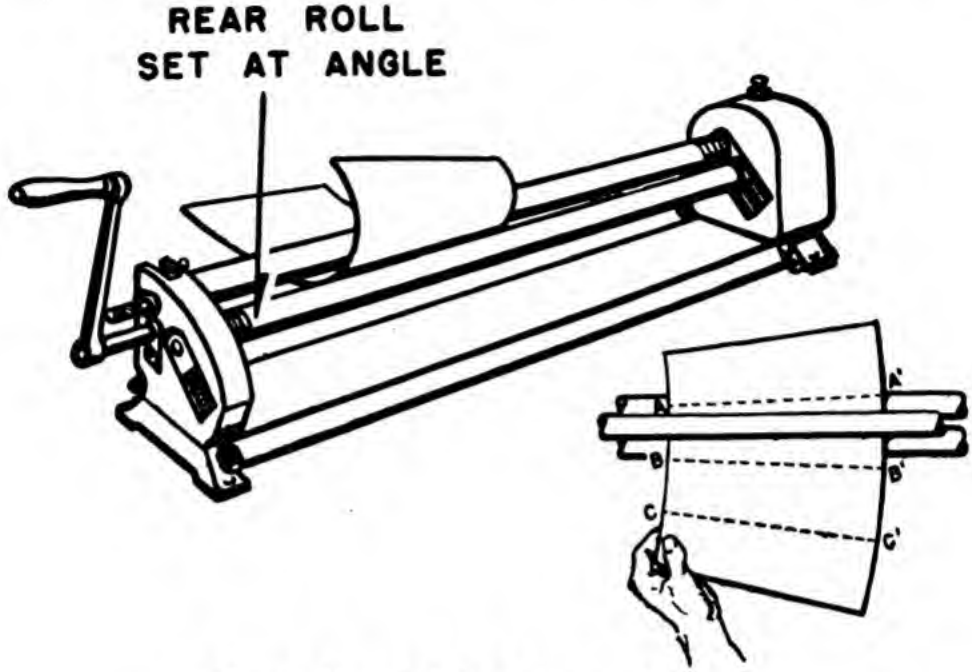


Figure 31.—Rolling a tapered shape.

until aa′ is under the center of the top roll. Then roll the sheet still farther and pull it back until bb′ is under the center of the top roll.

Repeat the process until the entire sheet has passed through the rolls.

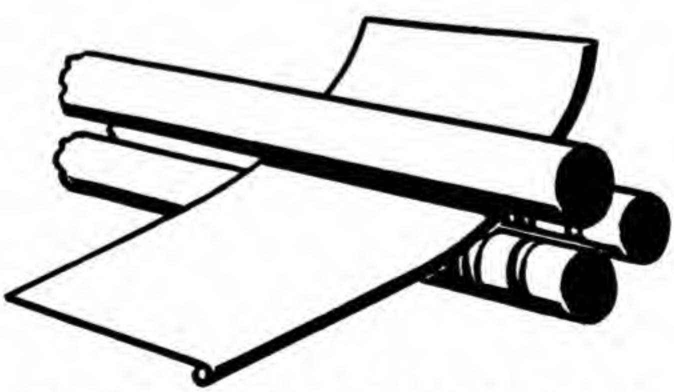


Figure 32.—Rolling a wire-edged cylinder.

When you want to ROLL A CYLINDER WITH A WIRE EDGE, set the machine so that the distance between the

upper and lower rolls is GREATER at the WIRE END than at the opposite end.

Then put the sheet between the rolls from the front of the machine, so that the wire edge fits into the proper-size groove in the rolls as in figure 32. The actual rolling job is like that of forming a flat sheet.

DRILL A HOLE

Another of the common operations you'll have to master in sheet metal work is DRILLING HOLES FOR

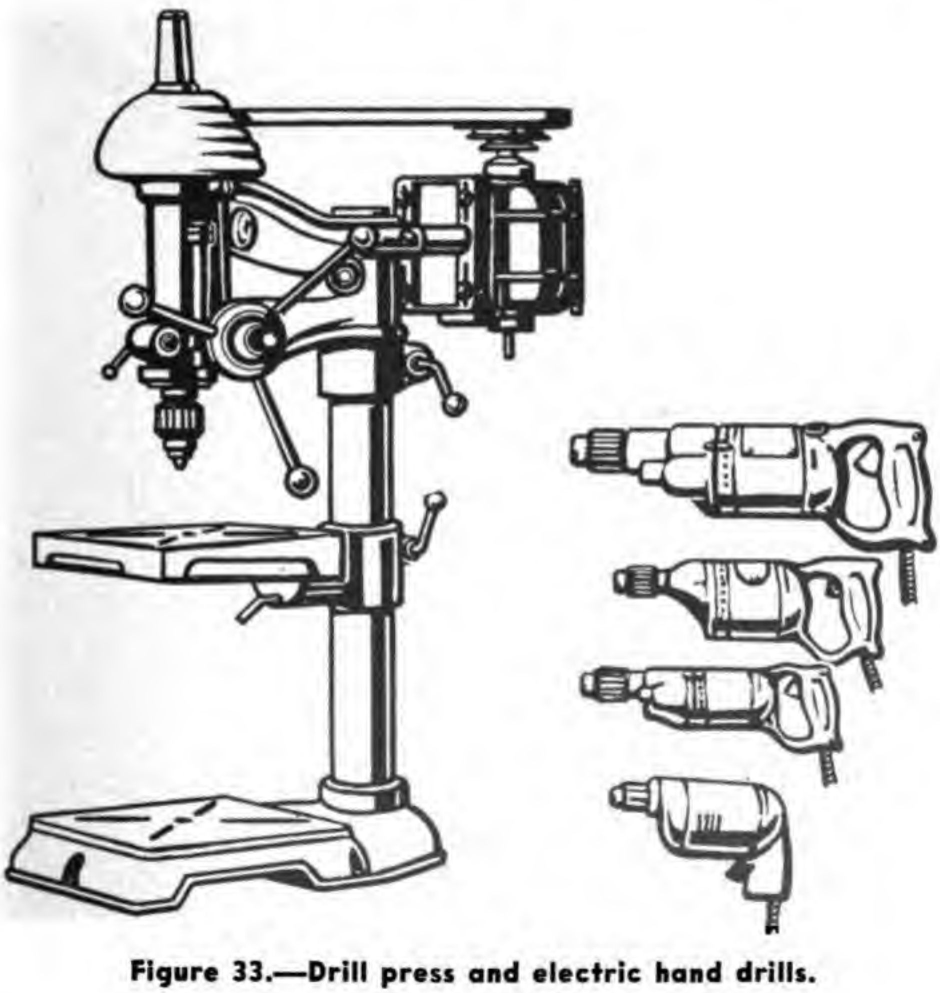


Figure 33.—Drill press and electric hand drills.

RIVETS. It's not hard to do, especially on light metal, when you have learned a few fundamentals about drills and their use.

In most cases, a small electric hand drill or a drill press is the most practical machine to use. A DRILL PRESS like that in figure 33, is usually best for drilling holes in flat stock. The HAND DRILL is best for drilling holes in formed structural pieces. You'll find it driven by either electricity or compressed air.

Some ELECTRIC DRILL motors operate on both alternating and direct current. Others operate on one kind of current but will not work on the other. It's important that you check to see which kind of drill you have, before you plug it in the outlet.

There are HEAVY-DUTY and LIGHT-DUTY types of

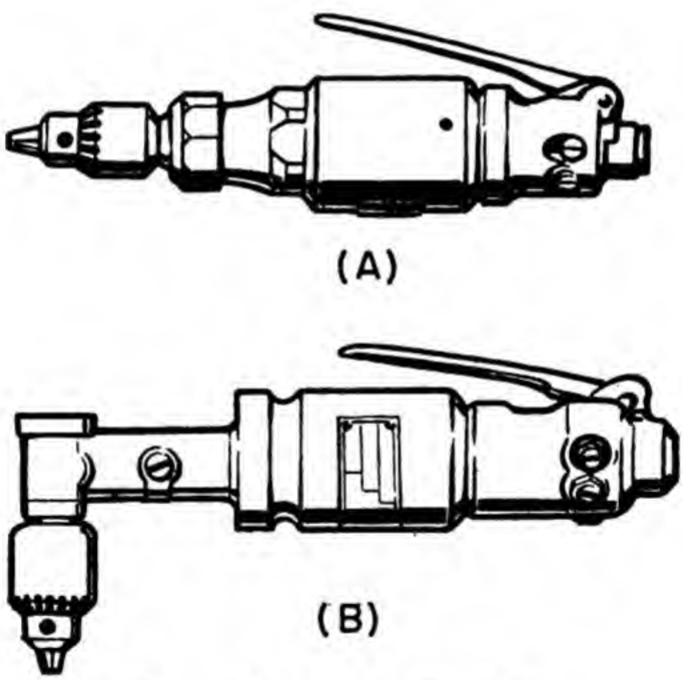


Figure 34.—Pneumatic drills.

drills. The light duty types are for occasional use while the heavy-duty types are designed for factory service. Special 45° and 90° angle drills are also made so that you can drill holes in places that are hard to get at.

PNEUMATIC drills work like electric drills except that they are driven by compressed air instead of electricity.

Pneumatic drills have some decided advantages due to the fact that you can CONTROL their speed by using

the throttle to vary the input of air. Thus you can start the drill bit at a slow speed until the hole is well under way, then speed it up. You can also stop the rotation of the drill bit more quickly with a pneumatic drill. This advantage saves you considerable time if you have to drill a lot of holes in quick succession. Pneumatic drills are available in the straight (*A*) and angle (*B*) shapes shown in figure 34.

Figure 35 shows two kinds of DRILL CHUCKS. A

(A) (B)

Figure 35.—Drill chucks.

drill chuck hole holds the drill bit and is made in sizes to correspond to the capacity of the drill motor. It has hardened steel jaws which are tightened and released with a threaded steel sleeve. The sleeve is knurled so that it can be turned by hand. Some KEYLESS chucks as in (*A*) are designed so that you can tighten them by hand pressure only.

The more common chucks have teeth on the lower edge and you apply the final tightening pressure with the key shown in (*B*). You don't have to knock yourself out tightening a chuck. A MODERATELY FIRM pressure is all that's necessary to tighten a good chuck.

SOME ATTACHMENTS FOR DRILLS

Many places in an aircraft where you might have to do some drilling are difficult to reach. For these jobs

you may want to use one of several different types of FLEXIBLE or ANGLE ATTACHMENTS.

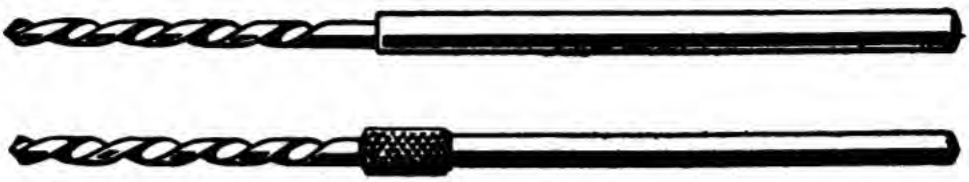


Figure 36.—Extension drills.

EXTENSION DRILLS like those in figure 36 are simply ordinary drills that have been welded to longer pieces of drill rod. They are made in various drill sizes and lengths and are used for drilling holes that are inaccessible to shorter drills.

Now comes the "pork chops." A pork chop, for your purposes in metal work, is a SPECIAL 45° or 90° ANGLE DRILL ATTACHMENT designed to allow you to get at

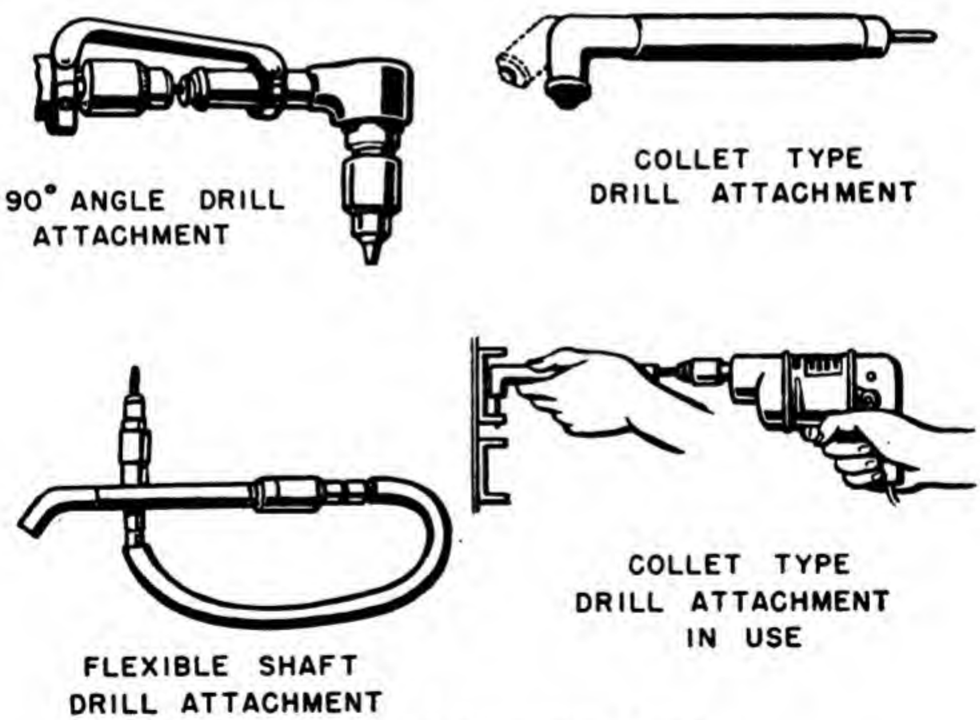


Figure 37.—Drilling attachments.

difficult places on aircraft structures. Figure 37 shows a number of drilling attachments.

Some of these attachments use a special drill with a

threaded shank that screws into the threaded spindle of the attachment. Others are equipped with a chuck which holds a threaded collet into which an ordinary twist drill is slipped.

A FLEXIBLE SHAFT drilling attachment is made of a flexible metal or of a high grade rubber casing. Such casings come in various lengths and head angles and are also designed for use in hard-to-reach places. The drill end of the flexible shaft is equipped with a collet chuck for holding a standard twist drill.

HOW YOU DO IT

Any riveting job you do depends for its success TO A GREAT EXTENT upon the HOLES you drill for the rivets.

The kind of metal you're working on, and the size and location of the rivet holes are all factors you must take into account in picking the appropriate type of portable drill motor and drill bit.

Here are some pointers.

Choose a high or low speed motor as required. In general, SMALL HOLES, ⅛ inch or less, in aluminum alloy are drilled at HIGH SPEEDS, usually 2,000 to 5,000 rpm. LARGER HOLES and holes in steel are drilled at SLOWER speeds. If you're using a drilling ATTACHMENT it's better to use a SLOW SPEED DRILL.

Your motor should be of convenient capacity, but within these limits. Pick one which won't be awkward or tiring to use.

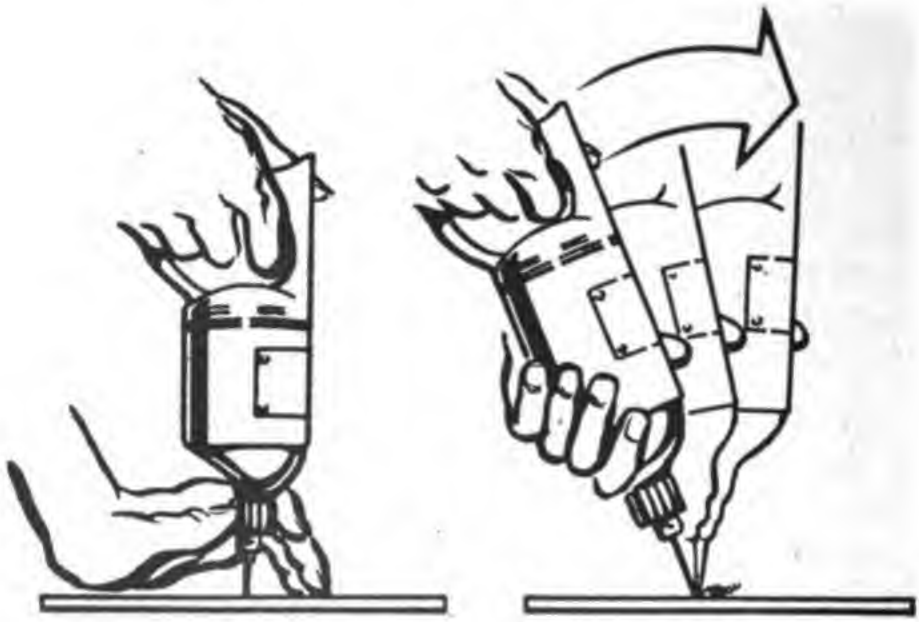
Use a drill attachment when you can't do the job with the available motor units.

Insert the drill bit into the chuck and tighten it securely, otherwise the drill will twist in the chuck and its shank will be marred.

Test it out. Start the motor and watch the point. If the drill doesn't run true, it may be because there are burrs on the shank or because the drill is not correctly chucked.

BE SURE TO HOLD THE DRILL PERPENDICULAR TO EITHER A FLAT OR ROUNDED SURFACE. Spot the drill DIRECTLY OVER the location of the hole as in figure 38 (A). Start the hole, then CHECK THE CENTERING by removing the drill as soon as it is well started.

If you find that the drill started off-center, you can correct the mistake, as in figure 38 (B) by tilt-



(A) (B)

Figure 38.—How to drill a hole.

ing the drill motor in the direction toward which the center must be moved to obtain a true hole.

Control the pressure you exert upon the drill. The drill should CUT its way—DON'T PUSH IT through the metal. Small drills will break if they are forced. Ease off on the drill after it has broken through the metal, in order to reduce the burr to a minimum.

CHAPTER 2

FORMING ALUMINUM

ALLOYS AND HOW THEY BEHAVE

Aluminum, as you know, is one of the most important metals used in the construction of today's airplanes. Many have so much aluminum in them they could be called "aluminum airplanes." Its popularity, of course, is due to its HIGH STRENGTH-TO-WEIGHT ratio, its resistance to corrosion and the ease with which it can be fabricated.

Because you'll be working a great deal with aluminum alloys, you might as well learn the first law of handling aluminum.

> TAKE IT EASY. Aluminum cannot be handled too carefully. Remember, scratched stock is scrap stock.

You must exercise constant care to avoid damaging the surface of aluminum sheet.

CLEAN OFF and cover all bench tops and beds of shears with paper.

Use BLOCKS OF WOOD to protect the metal from vise jaws.

CLAMPS and similar holding gadgets should be TAPED.

Scribers scratch the metal. So do all layout work with a pencil—not a scriber—unless the line will not be included in the finished part anyway.

Get someone to help you handle large sheets. It takes at least TWO MEN.

ANNEALING

Occasionally you may have to anneal aluminum alloys in order to soften them for greater ease in forming. Alloys 2S, 3S, 52S, which are non-heat treatable, receive their varying degrees of hardness by cold working. Thus, after repeated hammering, these metals become hard and must be softened before further forming can take place.

Alloys 17S, 24S, 53S, and 61S and Alclads 17S and 24S (heat-treatable alloys) can also be annealed either for relief of hardness caused by previous cold-working when the metal has NOT been heat-treated, or for relief of hardness caused by heat treatment.

In an emergency, it is possible to anneal aluminum simply with a welding torch. This method applies to strain hardenable aluminum. Take a welding torch and adjust it to have a clear EXCESS-ACETYLENE flame. The luminous, inner cone of the torch flame should be about SIX INCHES long.

Now play the flame of the torch back and forth over the metal until you have deposited a uniform coating of carbon.

Then quickly adjust the torch back to a strictly neutral (one-to-one proportion of oxygen and acetylene) flame. Use this flame to burn off the carbon coating completely by playing the flame back and forth over the metal. BE CAREFUL NOT TO BURN THROUGH THE METAL. That's what happens if you go woolgathering and forget to keep the flame in motion.

Another point to remember is that any forming which you do on aluminum must be followed by heat treatment after the part is finished. The reason for heat-treatment lies in the fact that stresses have been set up in the metal as you work it, which can only be EQUALIZED by heat treatment. By equalizing these stresses, you increase the strength and hardness of the alloy.

CORROSION PREVENTION

Corrosion prevention, in the form of a protective coating, is usually necessary with aluminum and aluminum alloys. This coating may be a lacquer or enamel or it may consist of what's called an "anodic" treatment. This last involves electrolysis, but don't get scared. You're not going into detail on this subject. Corrosion control is important, though, so here are a few facts to remember.

If you're using an enamel or lacquer, make sure your aluminum surface is clean. Then apply a primer, like zinc chromate. Now comes the lacquer or enamel —at least a couple of coats.

You use a primer in anodic treatment, too. Zinc chromate primer dries very rapidly, usually in about 5 minutes. You can apply it either with a brush or a spray gun. If you use a spray gun, thin the primer with two or three parts of toluol.

It is especially important to apply primer to the surfaces of two dissimilar metals which will be in contact. If you don't, an electrolytic action is started between them which causes corrosion. For instance, suppose you are attaching two pieces of aluminum alloy by means of a steel bolt. In this case the areas which will come in contact with the bolt must be thoroughly coated with a primer.

Corrosion also is hastened when there are scratches on the surface of an aluminum alloy, particularly on Alclad. It is general practice to protect aluminum alloy sheets from scratching by spraying on a coat of zinc

chromate primer, linseed oil, or varnish. This must be done BEFORE storing, or prior to handling for fabrication. The zinc chromate also provides a base for "laying out," as it shows up scribed lines.

HAND FORMING TOOLS

Forming is any operation which tends to change the shape or contour of a flat sheet. At the factory, aluminum sheet parts are formed by machine. But in the field, you'll find forming operations done by hand, because machines are seldom available. To do this forming by hand you'll use an assortment of mallets, form block and sandbags. Mallet heads for aluminum work are made of wood, rubber, plastic, micarta, or hard fiber to avoid scratching the aluminum.

NEVER use these mallets to hammer riveted sections on SHARP EDGES. If you do, the heads will become pitted and they'll be useless for finishing aluminum surfaces.

The flat-face wooden mallet is used, as in (*A*) and (*B*) of figure 39, for bending and planishing (smoothing out) dents in the surfaces of large sheet metal sections. A flat-face rawhide mallet is often used for the same purposes as a wooden one but is usually used where heavier blows are needed.

The ROUND-NOSE mallet is a handy device for BUMPING aluminum into molds as in (*C*). The size of the nose depends on the area of the surface you want to bump. You can also use a round-nose mallet for shaping metal over a sand bag.

A CROSS-PEEN mallet is the one you use for stretching and shrinking aluminum. In (*D*), you see the mallet used to stretch a piece of aluminum sheet. The cross-peen mallet is generally made of plastic, so that heavier blows can be struck without stretching the metal too rapidly.

A PLANISHING hammer has a metal head with slightly CONVEX FACES. It is used, as in (*E*), to smooth the

surfaces of parts which have already been formed. In some types of work the flat-face wooden or plastic mallet can be used for the same purpose. In planishing, you place the metal on a smooth, flat surface and then lightly strike the irregularities with the face of the hammer.

HOW TO USE A MALLET

The idea in using a mallet to form aluminum is to make the metal MOVE in the DIRECTION you have de-

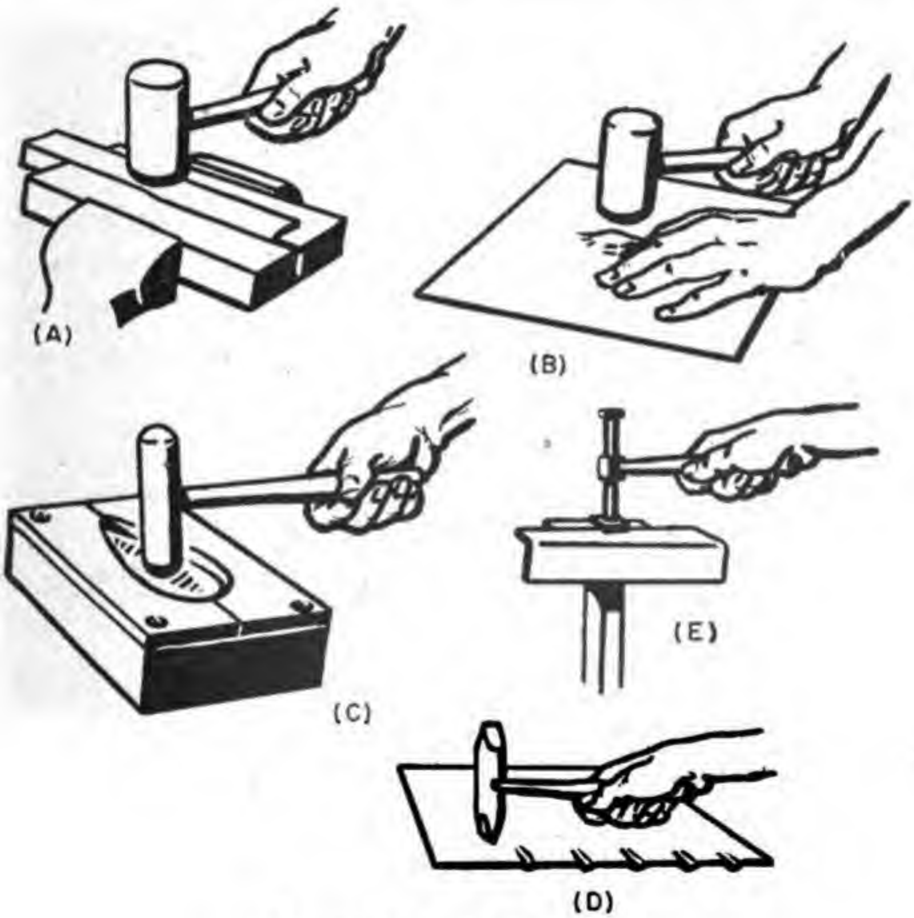


Figure 39.—Use of mallets.

cided upon. To accomplish this you must have good control over the striking power of the mallet. The swinging motion of your arm governs the force of the blow. If you want to strike a light blow, use only WRIST action as in (*A*) of figure 40. (*B*) shows the

combination of WRIST and ARM motion necessary to strike a heavy blow. In either case, hold the mallet near the end of the handle—not near the head.

In addition to picking the right type of mallet, you have to use some of the types of FORMING BLOCKS shown in figure 41. The shape and size of the blocks

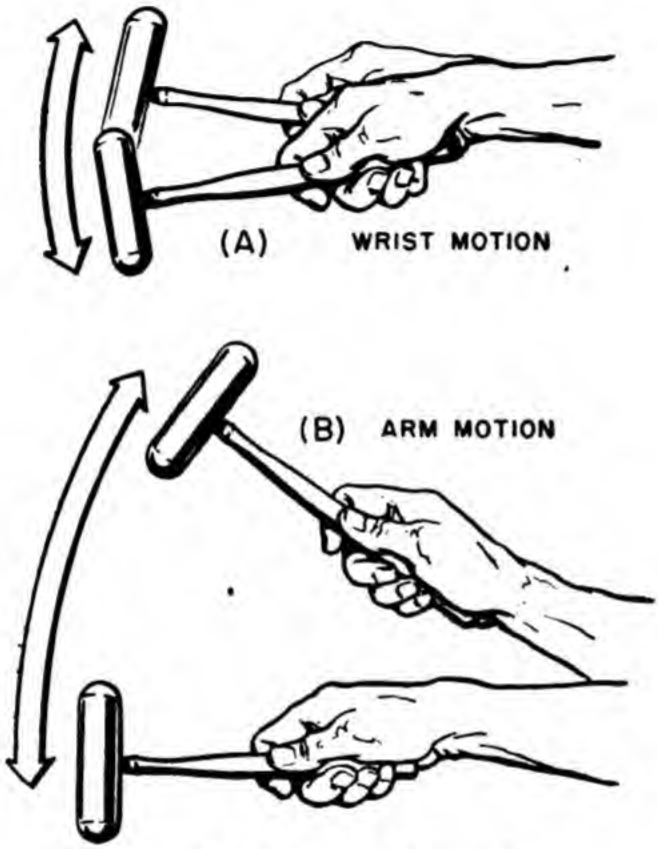


Figure 40.—Using a mallet.

may vary considerably, depending on the nature of the job. In some cases a special block may be necessary, and in others, two MATCHED blocks may be required. In any case, the blocks must be accurately shaped with very smooth surfaces.

If you only need to form a few pieces, the blocks are usually made from some kind of hardwood—often maple. They are shaped by means of woodworking tools like saws, chisels, rasps, gouges, sanding machines, and the like.

When a considerable number of pieces must be duplicated, the form blocks may be made of steel, micarta, or masonite.

If you want to planish a part you MUST use a solid

Figure 41.—Forming blocks.

backup surface. For curved surfaces, use blocks which conform to these curvatures. And this usually means using DOLLY BLOCKS. Dolly blocks are made of steel and have highly polished surfaces which won't mar the

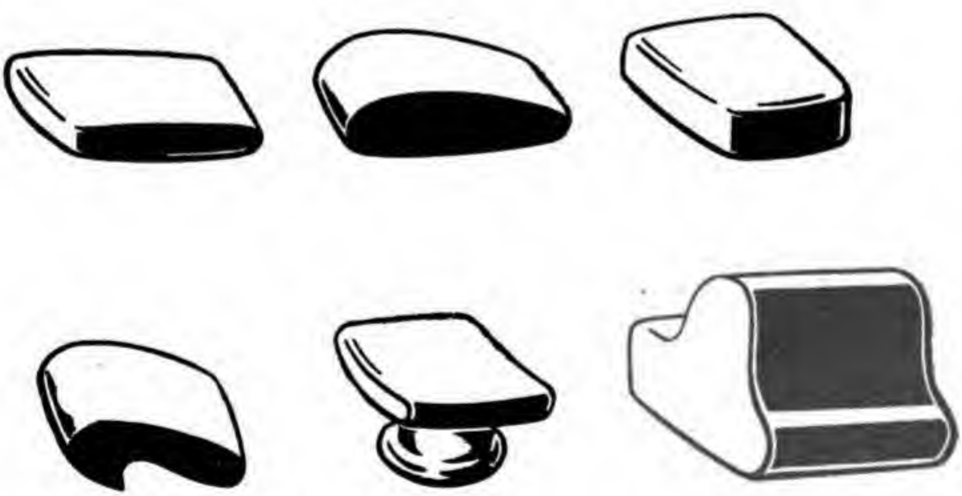


Figure 42.—Dolly blocks.

aluminum. They come in a variety of shapes like those in figure 42.

Dolly blocks may be held in the hand, or they may be fastened in a vise.

STRETCHING AND SHRINKING

What do you do when you want to make a curve, flange or some irregular shape in a piece of aluminum sheet? You stretch or shrink it. The amount of stretching and shrinking which you can get away with, depends almost entirely on what kind of aluminum you're using.

Fully annealed (that is, softened) 2S, 3S, or 52S, withstands considerably more of this kind of working than does 17S, and 24S, even if these last two alloys are completely annealed. The softer the material, the

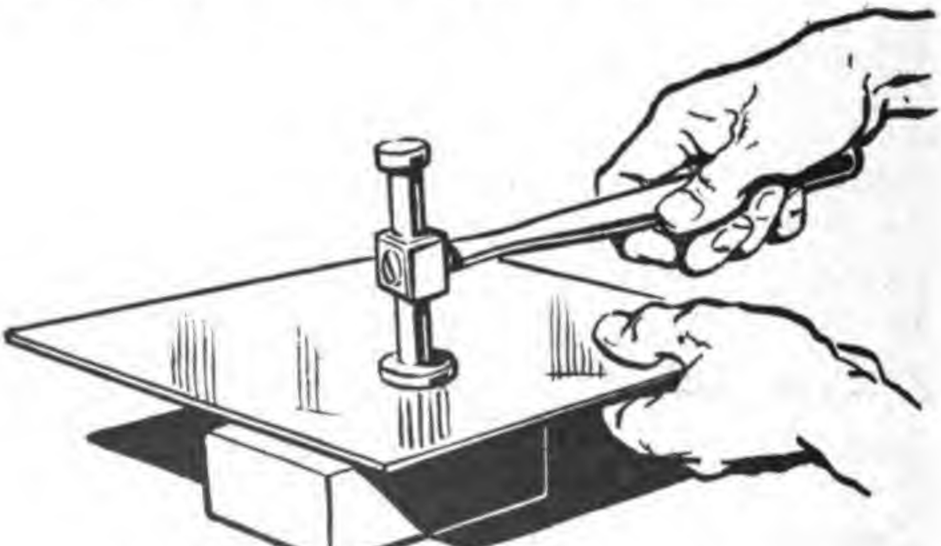


Figure 43.—A common way to stretch aluminum.

more hammering it can absorb, and the harder it is, the less it will take.

When you stretch aluminum, you increase the length or width of a particular area. Stretching doesn't necessarily hurt the aluminum, except that it thins it in about the same way a wad of chewing gum is thinned when you stretch it.

There are several ways to stretch aluminum. On ordinary flat pieces, a common way is to force the metal to flow outward toward the edges by hammering it over the surface of an anvil. Figure 43 shows you how.

By repeating this process and striking with a glancing blow in the direction the metal is intended to be stretched, you can lengthen the aluminum without creasing the surface. You have to be careful, however, NOT to hit the metal too hard or too long in one spot.

Each hammer blow must follow a CAREFUL PATTERN if you expect the surface to remain smooth and the stretching to progress correctly. Aimless hammering will only result in a spoiled piece of work.

STRETCH IT

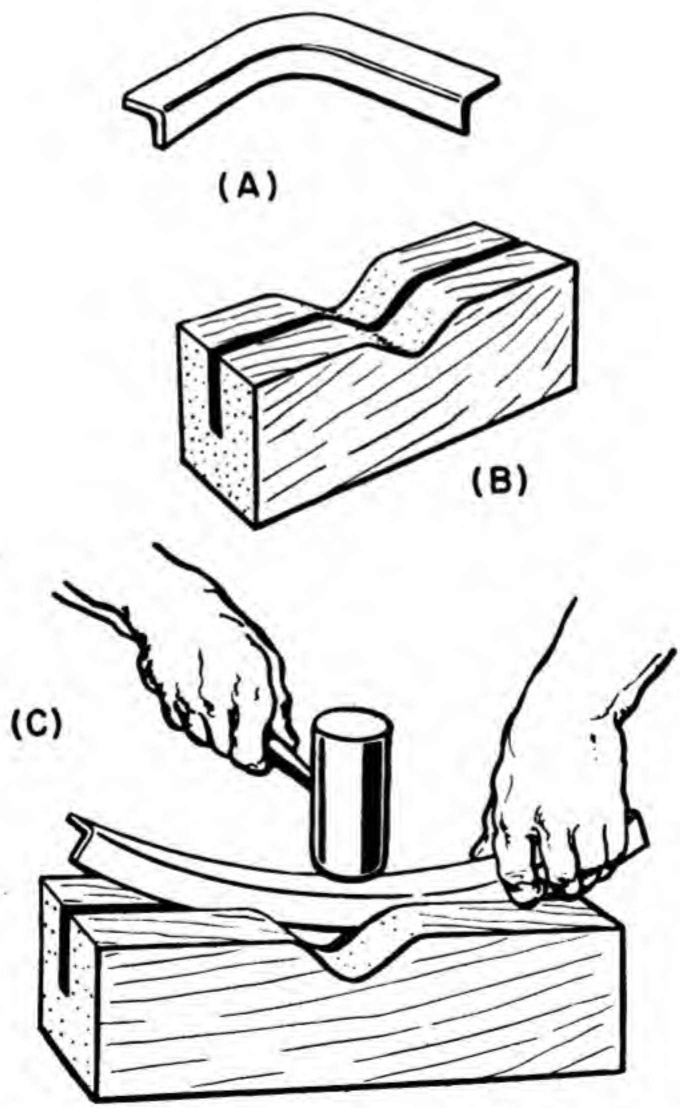


Figure 44.—Stretching an angle strip into a curve.

An angle strip can be stretched into a curve like that of (*A*) in figure 44 by stretching one of its bent flanges. Do this kind of stretching on a V-block, shown in (*B*), which has a slot to accommodate the angle and a V-shaped opening over which to hammer the metal.

Strike the flange of the angle strip CLOSE TO THE BEND and gradually force it downward into the V opening. Use a mallet or a suitable soft hammer and make your blows light so that you avoid buckling the metal. Move the angle strip back and forth over the V as in (*C*) until you obtain the right curve.

It's a good idea to have a pattern of the curve drawn on a piece of cardboard against which to check your work as you go along. When you complete the curve, remove any small dents or other irregularities from the piece by using a planishing hammer or a smooth, flat-face mallet.

SHRINK IT

Shrinking refers, obviously, to REDUCING the area of a piece of metal, by increasing its thickness. Shrink-

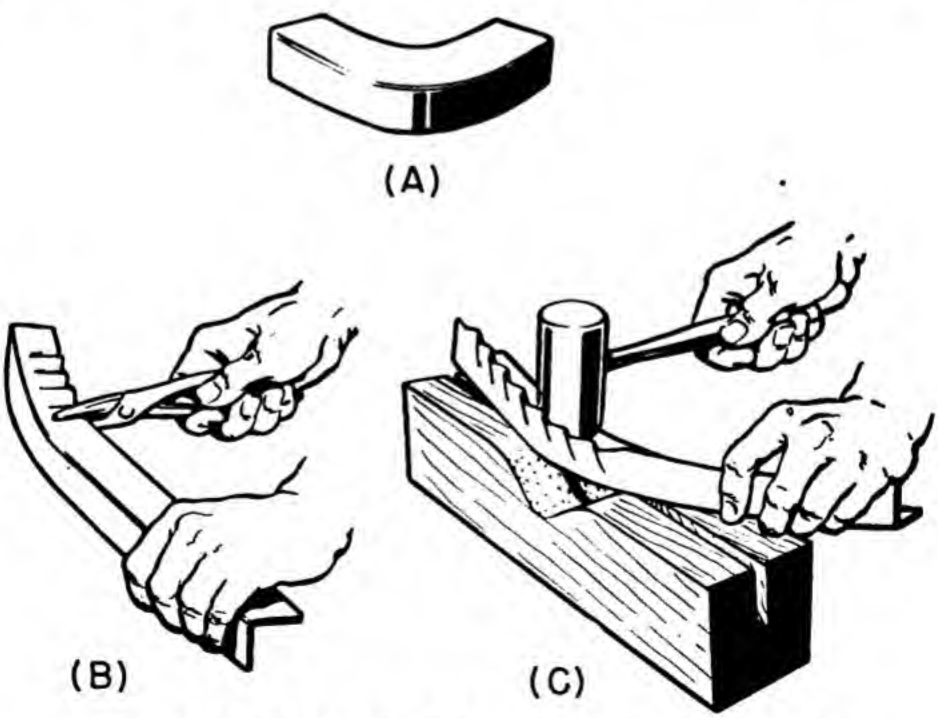


Figure 45.—Shrinking an angle strip into a curve.

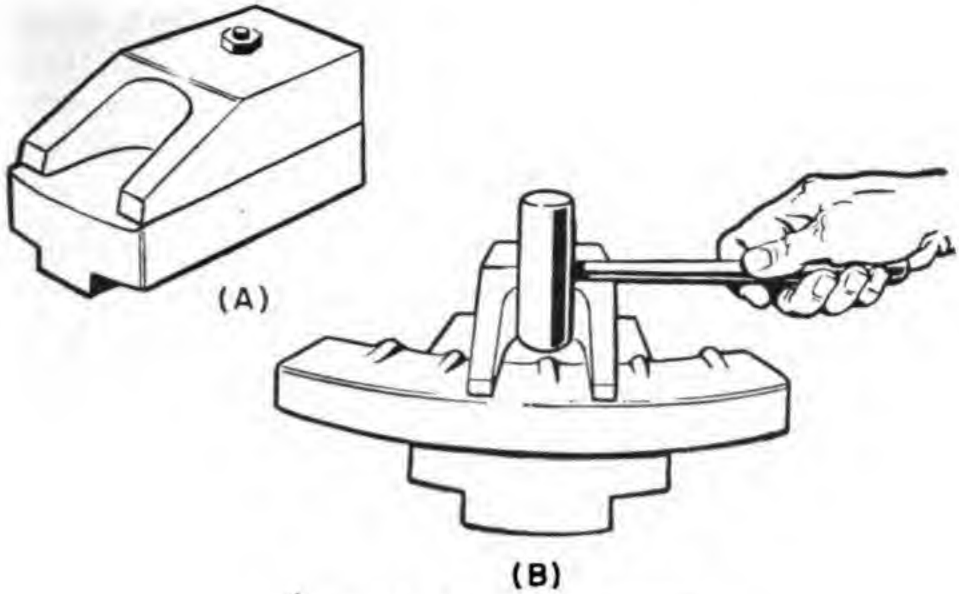


Figure 46.—Removing crimps.

ing is used to develop curves and to straighten flat pieces. Thus if a surface has been stretched too far, the metal must be shrunk back to its original shape. In some types of forming, as a matter of fact, you'll have to use BOTH stretching and shrinking to get the desired shape.

To shrink a piece of metal you have to CRIMP the edge, then hammer out the crimp. Suppose you want to bend an angle strip in a direction opposite to that shown in (*A*) of figure 44. It would not look like drawing (*A*) of figure 45.

To form such a curve you must SHRINK the flange. The first thing to do is make a series of evenly spaced crimps on this flange. For this job, either use a pair of round-nose pliers, or else hammer it over a V-block with a cross-peen mallet as in (*B*).

Hold the lower flange evenly on the V-block with the crimped surface on top as in (*C*). Hammer the flat surface lightly and uniformly with a mallet until you get the right curvature.

Finally, remove the crimps in the flange. First clamp the strip to some surface to prevent the curve from straightening out as you remove the crimps. A shrink-

ing block like that in (*A*) of figure 46 is best, or, you can use just blocks and clamps. Figure 46 (*B*) shows how to start the flattening AT THE APEX OF THE CRIMP. Then from the apex work gradually toward the base.

BUMPS

Many sheet metal parts of an airplane require special forming. At the factory, this special forming is

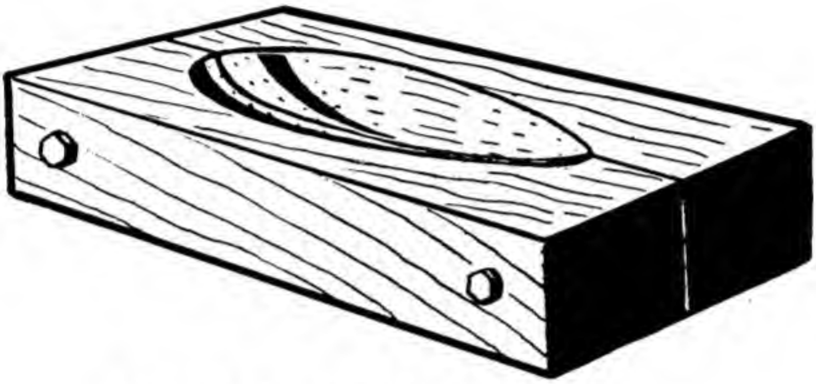


Figure 47.—Form block for bumping.

done by power equipment, which stamps or presses the part into shape. When such a part is damaged and must be replaced in the field, you will find that it is frequently necessary to form it by hand. First, stretch the metal by hammering it on a sandbag or on a form block which has been hollowed out to the required shape.

You can make form blocks of wood, lead, steel, or concrete. Maple is the usual choice for a hardwood block. It should be well-seasoned, free of knots and cracks, and straight-grained. Make sure it is large enough to provide sufficient backing for the flange. Generally, a one-inch extension beyond the hollowed part of the block is enough. The block may be gouged out from a solid piece of wood, or it may be made up of two lengthwise halves held in place with steel rods, as in figure 47.

After you have finished gouging out the block, smooth the surface with sandpaper. If the block is to be used repeatedly, it can be made of steel. A block made of lead can be recast into another shape after the original shape has served its purpose—which is sometimes an advantage. For forming large sections, concrete forms are sometimes used. These should be reinforced around areas where the forming is severe. A concrete form is usually lined with a rubber sheet or a felt mask to protect the surface of the aluminum sheet which you are working. Such a sheet or mask may be shaped over the mold form and then transferred to the concrete form. Secure it with glue or shellac.

YOU NEED A PATTERN

In order to gouge out the depression in a form block, you'll have to have some method of checking the progress of your work in order to make sure that you come out with the right shape. The answer is to use a tem-

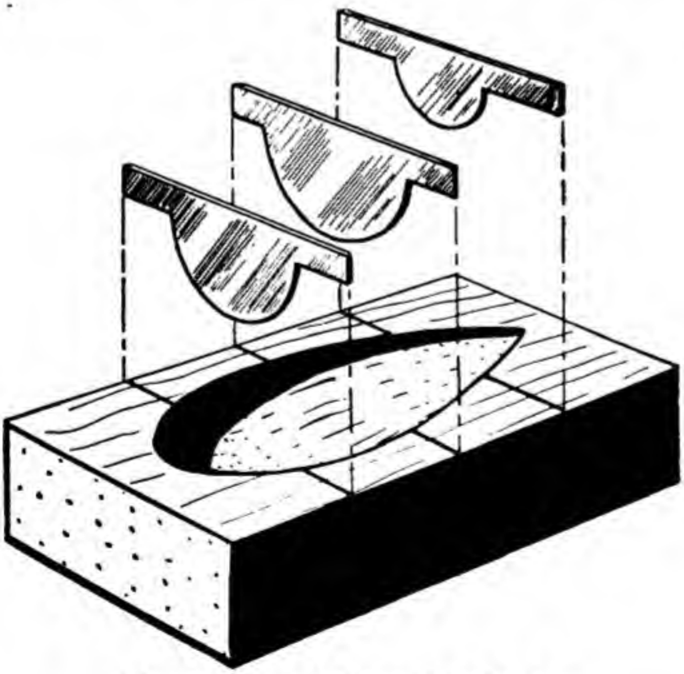


Figure 48.—Making templates.

plate made from some scrap material. You can use either of two methods.

The first way is to make three or four templates, each of which fits a definite position in the form block CROSSWISE in relation to the depression. Such templates are usually laid out semi-circular, with the radius equal to the depth of the depression at the position each is to fit, as in figure 48.

A second and more accurate method of using a template for checking purposes is to make one which is applied lengthwise in the depression. It is a half section of a streamlined curve. You rotate it as an axis about the center line of the depression to check the entire surface.

Look at figure 49. Here you have a HOLD DOWN PLATE. Such a plate is used on top of the form block.

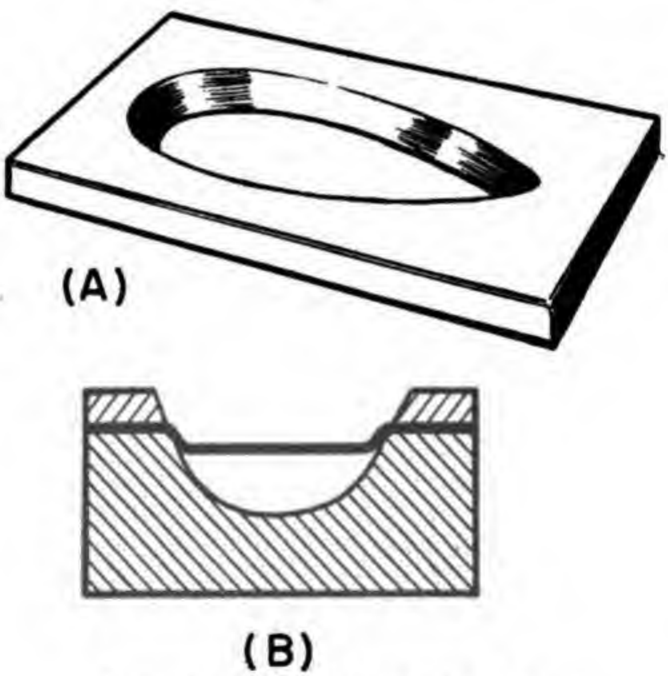


Figure 49.—A hold down plate.

Its purpose is to keep the metal in place and to make sure that it is SECURELY IN CONTACT with the form block while it is being bumped. A hold down plate can be made of mild steel, plywood or any other material that is strong and stiff enough.

Be sure that the opening in the hold down plate actually matches the outline of the depression in the form block. It should be beveled so that you can hammer close to the upper edge of the depression.

Arrange the hold down plate so that some of the metal will be permitted to slip into the mold. This is a good idea because the metal is stretched as it is being hammered into the mold, and such stretching thins it out—especially in the center. Thus, if the aluminum can be permitted to slip into the form AS YOU HAMMER, this thinning can be considerably cut down.

In order to be suitable for bumping, an aluminum alloy should be FULLY ANNEALED or in its dead soft condition. If the material is a heat-treatable alloy, you should heat-treat the part after it is formed in order to jackup both its strength and its corrosion resistance.

TRY A BUMP

Pick an alloy of the correct kind and thickness and cut out a rectangular piece to dimensions. But be sure to allow a one-inch margin. Put the piece symmetrically on the form block. Set the hold down plate on top of it and fasten it in place with C clamps tight enough to prevent excessive buckling in the flanges during bumping. The hold down plate should not be fastened so tightly, however, that it will prevent the metal from slipping as it is pulled into the form. If you DO fasten it too tightly, you'll let yourself in for trouble because the aluminum will not be able to slip in the frame and will be unduly thinned. Under such circumstances, you will be lucky if it doesn't rupture while it is being hammered. So remember, NOT TOO TIGHT.

Begin your bumping operation by hammering the metal around the EDGE of the opening in the hold down plate. Use a soft, round-nosed hammer of wood or pyrolin. Look at figure 50 which shows the correct way to pound the metal. You should hammer so that the

metal always follows the form while it is being stretched down into the block. In this way, as you can see, it is partially supported while being hammered. Make your blows light and repeat them many times.

For large areas where you want a very smooth surface, use, instead of a hammer, a small leather bag

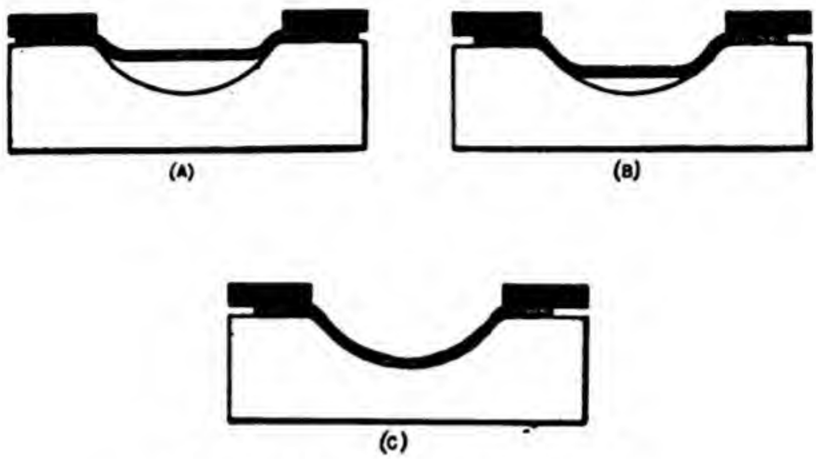


Figure 50.—Bumping procedure.

filled with shot, which is called a black jack. With a black jack, no tool marks are made and it is possible to shape the metal rapidly.

WATCH OUT FOR HARDENING

As you work, keep one eye peeled for indications of hardening. Such a condition, known as strain or work hardening, is a result of the work you are doing upon the aluminum. How can you tell? The metal will tend to become springy, or the surface will have a grainy look, sort of like the skin of an orange. When these warning signs appear, don't disregard them. Stop and anneal the aluminum.

If you continue hammering after the strain hardened condition develops, you may find the aluminum cracking. Then your part is a TOTAL LOSS. As a matter of fact, it may be necessary to stop several times dur-

ing the forming operation to anneal the part in order to relieve strain hardness.

When you have finished stretching the part into shape in the form, check up to see whether there are hammer marks or roughness which should be removed. One way to remove these marks is to rub them with a round-nosed hardwood stick. Another, and probably a better way, is to take the part out of the form block and use a planishing hammer and a suitable dolly block.

When you have finished the bumping operation and the part is ready to be installed, it should be heat-treated, anodized, primed with zinc chromate primer, and painted. If the alloy you used is strain hardenable, you can omit the heat treatment.

REMOVING DENTS

One of your most common jobs as an Aviation Metalsmith will be to straighten out aluminum surfaces that

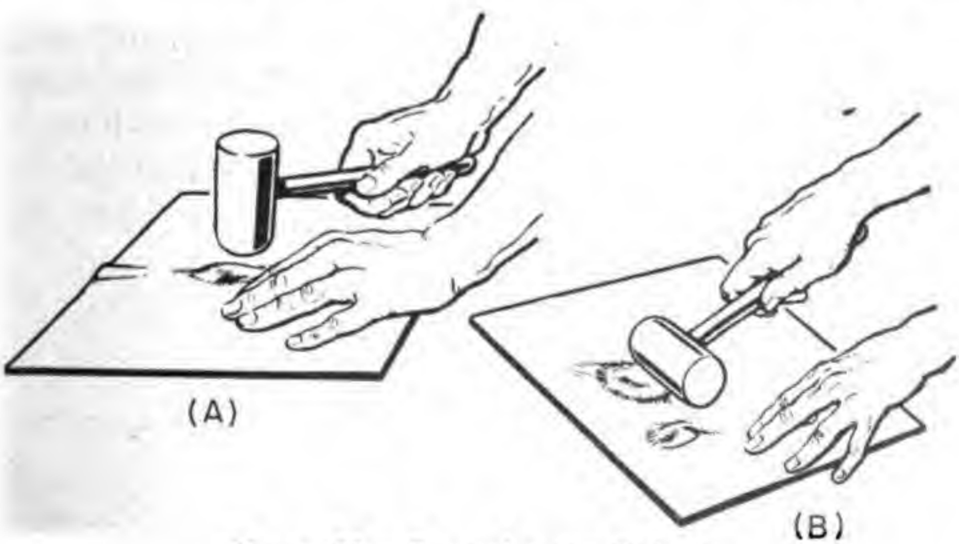


Figure 51.—Removing small dents.

have been DENTED. If you go about it correctly, you can restore a dented surface to its original shape and finish. Cowlings, wheel fairings and tail surfaces for example, are parts of an aircraft which often become dented.

It is a good idea to plan your strategy carefully before you start to hammer out a dent. If the dent is small, put the CONCAVE side of the damaged surface on a metal stick or hardwood block. Hammer the dent lightly with a flat-face wooden mallet. Start hammering around the edge and gradually work toward the center of the dent as in (*A*) of figure 51. Be as economical as you can with your hammer blows, because each blow stretches the metal a little.

If you have a large buckle to repair, the best way to do it is to place the surface of the part on a hardwood backing block. PRESS the metal back into place instead of hammering it. Start at the edges of the dent and press and roll the metal, holding your mallet in the position shown in (*B*) of figure 51, gradually work in toward the center from the edges.

Sometimes a large bulge which is not complicated by creases can be straightened simply by directing an even blow at it or by PUSHING the center of the buckle so that the metal snaps back into place.

You may find it possible to straighten out large bulges in which the aluminum has been stretched excessively by SHRINKING THE AREA and then smoothing out the folds. If these tactics aren't possible, then the best thing to do is to cut out the whole area and put in a patch.

On most pieces you will find that irregularities still

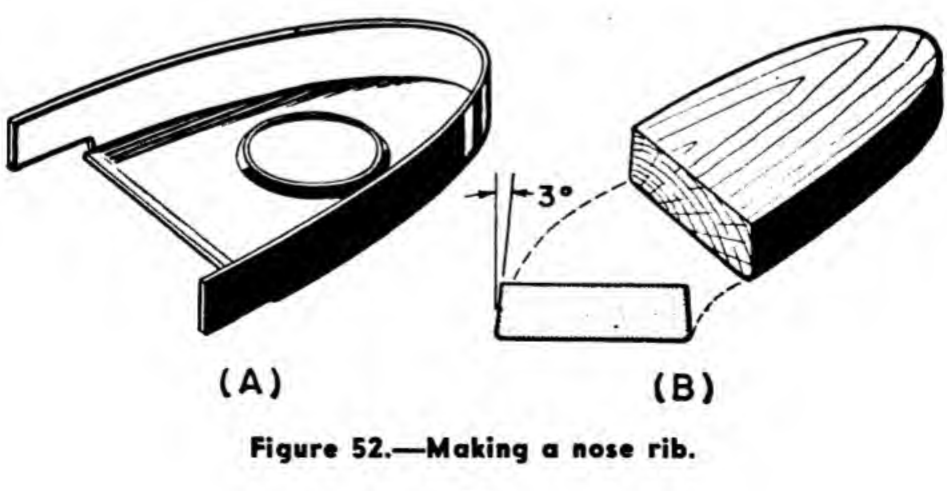


Figure 52.—Making a nose rib.

remain after you have removed a dent. To smooth them out, use properly shaped dolly blocks and either a flat-face mallet or a planishing hammer. Sometimes you may find that the hammered area will have to be filed. This is ticklish business. TAKE EXTREME CARE NOT TO FILE SO MUCH THAT YOU WEAKEN THE METAL. As a final smoothing out process to eliminate scratches or other small irregularities, rub the surface of the part with steel wool or with a very fine abrasive cloth.

FLANGING

When you have to make an airplane part, you'll often find it necessary to FLANGE the edges. A straight right-angle flange is pretty easy to form. But the job becomes more difficult if you have to make a flange on a curved surface.

Suppose you want to make a nose rib like that in (*A*) of figure 52. The first step is to draw the outline of the rib on two hardwood blocks and then cut them out with a bandsaw. You must round the edge of one block slightly in order to produce the required radius of the bend. Then this same block must be beveled anywhere from 3 to 11 degrees, depending on the spring back—that is, the hardness—of the metal. Figure 52 (*B*) shows this beveling. Finally, smooth the edges of both blocks with a rasp and sandpaper, or use a circular disk sander if you have one available.

HOW TO FORM A FLANGE

Take a piece of the proper type of aluminum, being sure that you allow sufficient metal for the flange and later trimming.

Draw the shape of the rib on the aluminum. Now draw a line around the curved edge of the rib to represent the desired width of the flange plus the trim, approximately 1/4 inch. Cut along this outside line with a pair of snips as in figure 53.

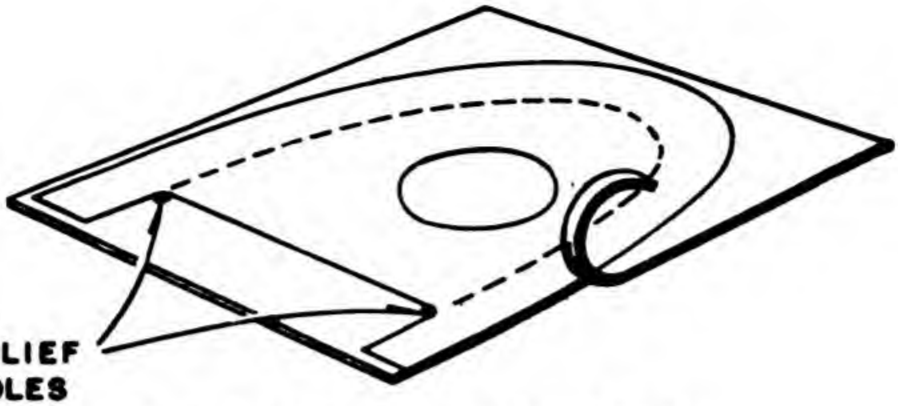


Figure 53.—Cutting along the flange.

Next, lock the metal between the two form blocks, using clamps. Be sure the guide lines are even with the edge of the blocks. You can hold the blocks and metal firm by putting them in a vise, as (*A*) in figure 54 indicates.

Now you can start bending the flange along the curved portion of the rib with a cross peen mallet made of wood or plastic. Do this gradually, striking the first blows close to the radius of the form blocks but not directly over it. Gradually move the blows a little closer to the edge and along the entire curve.

In completing the curved portion of the flange, you will have to use a wedged wooden block with your cross peen mallet. Figure 54 (*B*) shows how this is accomplished, and it indicates the shape of the wedge block.

Start hammering on the curve at the INSIDE edge of the block, where the metal is bent to form the flange. Then you insert the wedge block under the wrinkles that will form on the OUTER edge of the flange and keep striking the metal away from the edge of the wooden form block.

At this point you will find that you have some excess material left to be trimmed, because cracks often form along the edge when the wrinkles are removed. Measure off the exact size of the flange you want with calipers or a marking gauge. Then cut off the excess with aviation snips. Burrs may be removed with a file. You

can eliminate any other irregularities in the surface of the metal by planishing while it is still on the form block.

HOW TO MAKE A FLANGE AROUND A HOLE

Holes for weight-relieving purposes are often made on sheet metal parts. To help in stiffening the area around the hole the edges are often flanged. You can make such a flange in one of two ways. The first way, shown in (*A*) of figure 55, is to lightly hammer the edge over a correctly shaped block until the necessary flange is made.

The other way is to use a flanging die like that in (*B*). If you are going to use it for soft metal the die can be made from two hardwood blocks. Such a die is fairly easy to use. You simply cut an opening in the metal and then place the metal piece on the lower block which has a hole in it. Then fit the upper block into place over the metal and strike it with a mallet.

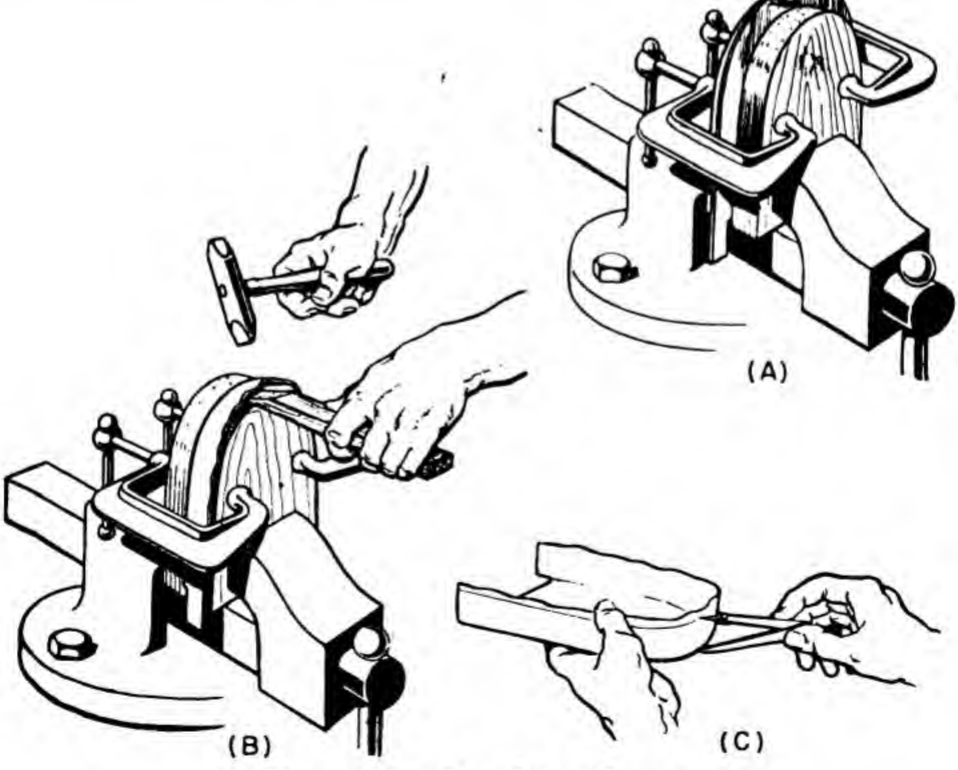


Figure 54.—Forming a flange.

SANDBAG BUMPING

Sandbag bumping is a way to form metal by using a FLEXIBLE BAG which has a depression in it, plus a MALLET. As you know, there are lots of small parts of an aircraft which must be formed by shrinking or stretching. They cannot be shaped in a brake, bar folder, or slip roll. Forming such a piece in a wood form block or steel die has already been described. These are best if you must make several pieces of the same contour.

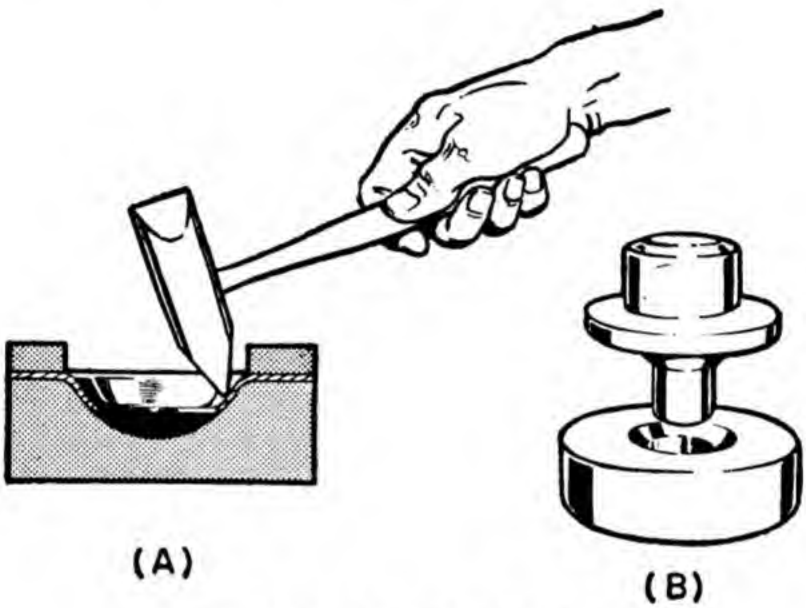


Figure 55.—Flanging an opening.

But you can also shape a part into a depression in a sandbag.

Sandbag forming can be used for a variety of jobs which range from removing a simple dent in a cowling to making a complicated streamlined fairing. Such forming is often more convenient and economical than using form blocks or steel dies.

REMEMBER, BUMPING can be done ONLY on MALLEABLE metals. In aircraft construction and repairs, nonstructural parts that require bumping are usually made of a softer alloy like 2S, 3S, or 52S. When a part to be bumped MUST be made of a heat-treatable alloy, the

metal must be in a dead soft condition. And whatever alloy you use, you must be sure to keep it malleable by frequent annealing.

Look at figure 56 which shows metal being bumped on a sandbag. A sandbag is made of some durable

Figure 56.—Sandbag bumping.

closely woven material like heavy canvas or soft leather. If the bag is made of canvas, it should be dipped in wax to close the pores of the cloth. Of course in an emergency, any tough, heavy fabric would fill the bill. The filler is usually fine, dry sand which remains flexible and doesn't form hard lumps.

The size and shape of the hammer or mallet you use will of course be determined by the kind of forming which the job at hand requires. Then in addition, you will sometimes find it necessary to use dollies, a planishing hammer and stakes to do the finishing operations after the metal has been bumped.

A FEW GUIDE POSTS

Before you do any forming on a sandbag, you'll save yourself a lot of woe if you first take time out to figure a plan of attack. Don't go off in all directions at once. Study the job. Figure out where the greatest amount of stretching must take place. Decide where the forming must begin and how it should proceed.

Pick a mallet of the CORRECT WEIGHT AND SHAPE for the job at hand. In general this means using a small mallet for jobs with sharp curves. For work which requires more gradual curves, you'll need a larger mallet. What happens if your mallet is too small? The thinning of the metal is spotty. It will look bumpy. And, on the other hand, you cannot develop curves of small radius with a mallet which is too large.

Check the original part or a drawing of it to make sure that the METAL you select is of the proper alloy and correct temper. See that you cut the piece large enough to allow for the shrinking and stretching that must be done. Burr all the edges so that cracks won't develop during the forming operation.

USE THE CORRECT PROCEDURE. Always form a depression in the sandbag with a curvature which approximately matches that which you want in the finished article. As you bump the metal, be careful to see that each blow overlaps a previous one. Work in concentric circles—that is, begin at the outside of the piece and work toward the center.

Check the project frequently. As you go along, use a template or the original article to check the contour. This is very important because if you forget and allow too sharp a curve to develop at any one point, it is almost impossible to remove since the metal has been stretched. Trying to remove it may result in an oil can.

Watch out for signs of strain hardening. Warning signs are a change in the ringing tone of the metal when you strike it, or increasing difficulty in forming it. Whenever these signs appear you must stop and anneal the metal.

After completing the forming, you'll usually find it necessary to take out the small irregularities by planishing. To back up the work while you are planishing, use either smooth highly polished dollies, or a stake. If stake is necessary be sure it is free of rough spots or scratches which might mar the aluminum.

Repairing or making metal parts on a sandbag varies

with the individual job. The descriptions of specific jobs which follow will apply to various cases.

HOW TO DO IT

Suppose you want to remove the dents from a cowling or fairing. First, remove the part from the airplane. Then shape the sandbag to match approximately the curvature of the original piece. Place the metal on the bag so that the dent can be pounded out from the inside.

Pick the right mallet and begin working on the dent near the edge, hammering in toward the center until the depression is gone. Be stingy with the number of blows you use to avoid strain hardening the metal.

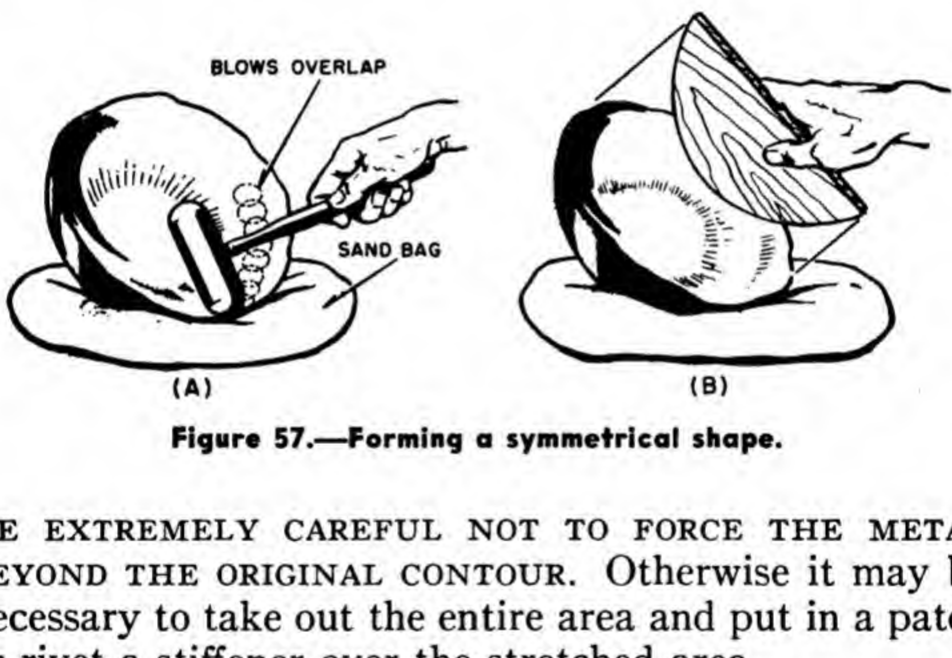


Figure 57.—Forming a symmetrical shape.

BE EXTREMELY CAREFUL NOT TO FORCE THE METAL BEYOND THE ORIGINAL CONTOUR. Otherwise it may be necessary to take out the entire area and put in a patch or rivet a stiffener over the stretched area.

Last of all, support the metal with a highly polished dolly while you remove small irregularities with a flat-faced mallet or planishing.

This is the way to form a SYMMETRICAL PART. Cut the aluminum about one-inch oversize and then file all the edges. Hunt around until you find a mallet of the right size and shape. Prepare a template or use the original piece as a forming guide.

Hold the metal in one hand at an angle of about 30°

over the depression in the bag. Now start at the outside edge and strike overlapping blows, as in (*A*) of figure 57. As you rotate the metal work steadily and gradually from the outside to the inside in concentric circles. Check your work frequently as shown in (*B*). Use either the original piece or a template to make sure that the correct shape or curve is being formed. To finish the piece, put the inside of the curve over a round

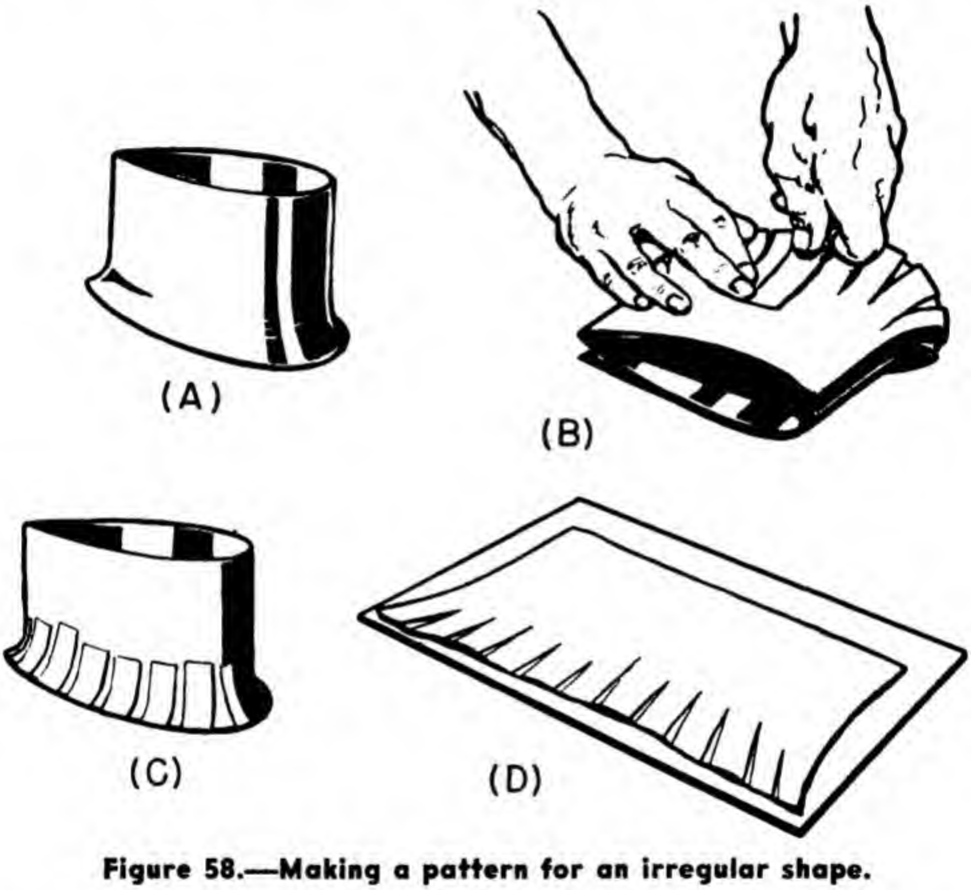


Figure 58.—Making a pattern for an irregular shape.

head stake which has approximately the same curvature, and then planish all the hammer marks.

To make an irregular shape like the fairing in (*A*) of figure 58, you must have a suitable template. You can get the general shape and outline of the part by fitting a piece of heavy paper around the part to be duplicated. Figure 58 (*B*), shows a piece of paper being wrapped around a fairing. The paper is cut wherever necessary to make it take shape more readily. Then

the cuts are covered with masking tape as in (*C*), so that the paper may be fitted exactly to the shape of the part.

Now cut your pattern away from the fairing. Make the cut directly over the SEAM of the fairing. Then remove the masking tape from the pattern and lay the pattern out on the metal as in (*D*) of figure 58. Use a

Figure 59.—Bumping a fairing.

red pencil to mark the pattern cuts on the metal. Be sure to allow extra metal around the outside of the pattern for trimming. You will direct most of the blows in bumping the piece along the lines marked on the metal from the cuts in the pattern. The metal stretches most at these points.

Now pick a mallet of the right shape and tap a general outline of the part into the sandbag. Be careful not to make it too deep.

The next thing to do is to place the metal over the sandbag and start bumping as in figure 59, using many LIGHT blows so that the metal will stretch evenly.

WORK THE ENTIRE PIECE. In this way all the various curves GRADUALLY take the desired shape as your work progresses. You may have to anneal the part if it becomes too brittle or hard.

If necessary, try the part on the airplane for size until the proper shape and fit is obtained. Of course if a template or the original part is available, you can use either one to check the progress of the part as it is being formed.

Planish the work to remove small dents but be careful not to hammer it too hard because if you do you will stretch the metal beyond its desired shape. It cannot be restored once this is done.

After the forming is completed your piece should be heat-treated, anodized and primed.

ABOUT JOGGLES

You have a JOGGLE when a bend is made on a flat

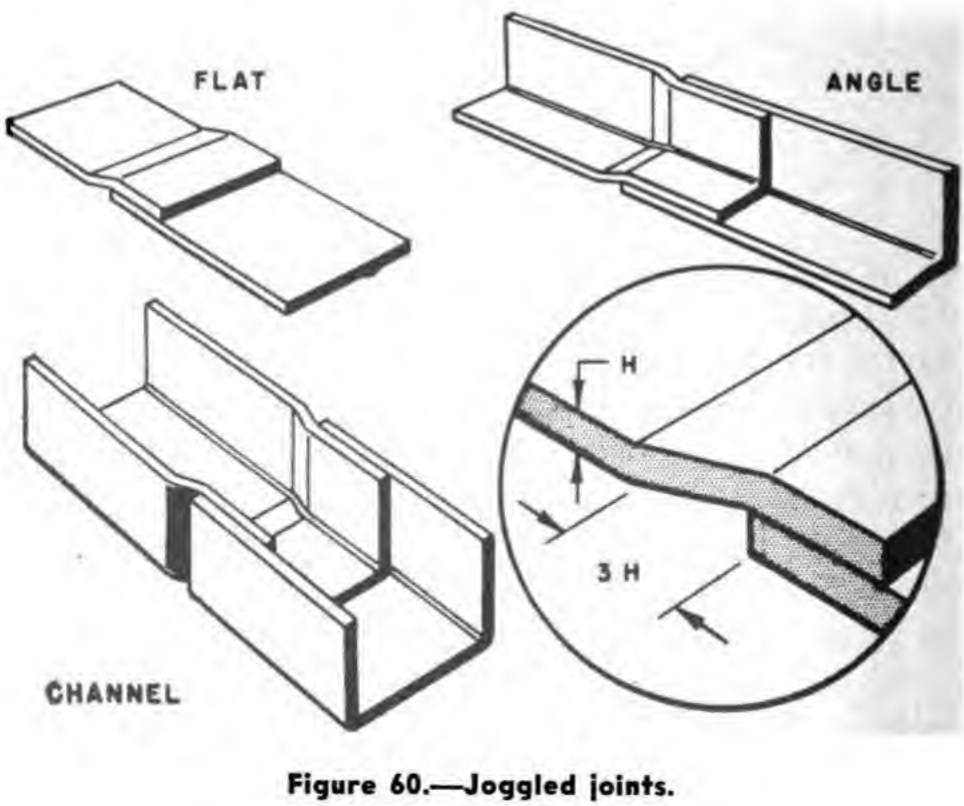


Figure 60.—Joggled joints.

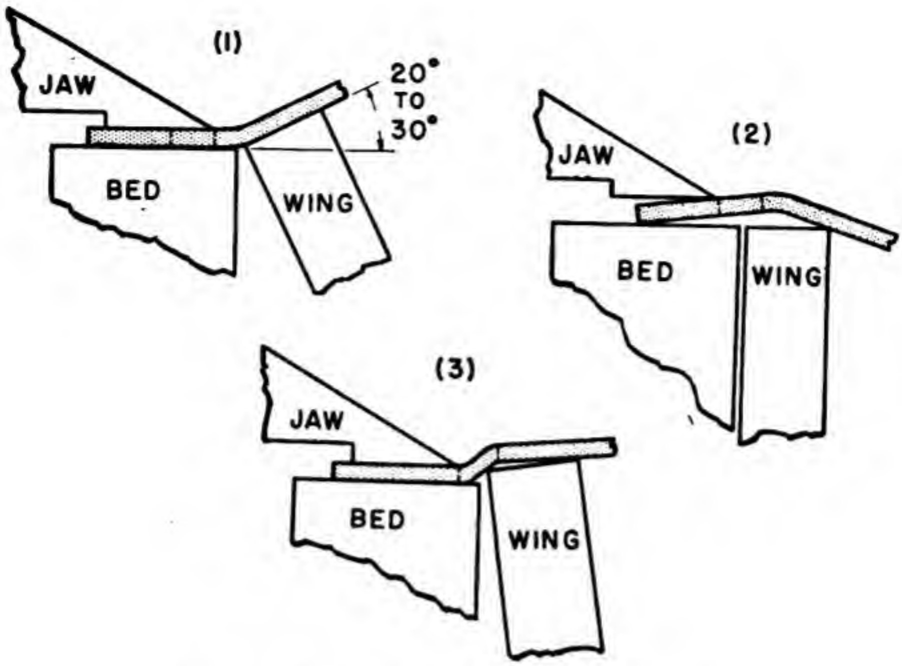


Figure 61.—A joggle in a flat sheet.

sheet, angle, or channel to permit two overlapping pieces to form a level surface, as in figure 60.

On a flat sheet such a bend can easily be made in a BRAKE. But in angle strips or channel pieces, you have to use a specially designed joggling block. It is best to avoid joggling as a rule, where the offset is .032″ or less. But if the under skin is so thin that riveting an ordinary lap joint would produce a dimple in this under skin, then a joggle must be used in the upper skin, even though the offset is .032″ or less.

To form an effective offset, the length of the joggle should be approximately three times its height. Figure 60 shows these dimensions.

The first step in forming any joggle is to lay out the boundary lines where the bend is to occur. If the offset is to be made on a BRAKE, clamp the piece between the jaw and bed as shown in figure 61. Bend one leg approximately 20° to 30°. Then turn the piece over and clamp it in the brake. Raise the bending leaf of the break until the correct offset is produced.

If the offset is to be made in angle strips or channel

pieces IN A JOGGLE BLOCK, then you simply place the angle or channel between the two sections of the joggle block. Fasten it in a vise or some other suitable clamping device. After the joggle is formed, turn the joggle blocks OVER. The bulge on the opposite angle is flattened with a wood mallet.

Sometimes you will want to make an angle or channel from flat stock.

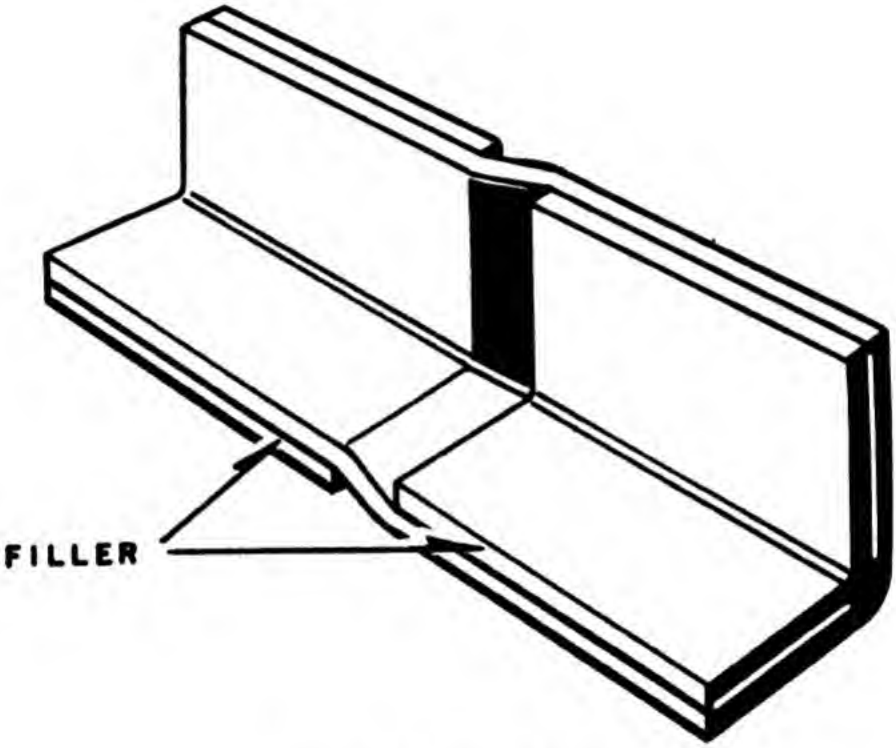


Figure 62.—Joggled angle.

To make a jogged angle or channel from a flat sheet, start by joggling the flat sheet with vise and mallet as previously described. Then you place a filler piece of metal on each side of the joggled flat sheet, as shown in figure 62. Note that the fillers should be the same width as the joggled sheet. Now bend the legs of the angle or channel in the brake with the filler pieces in place.

BENDING ALUMINUM ALLOY

TAKE IT EASY when you bend aluminum alloy! You will find that alloy which has been formed to a sharp angle is not as strong as when it has been formed to a rounded corner. Even though aluminum alloys are malleable, they will crack if bent too sharply. Since aircraft design places so much emphasis on the strength of the various parts, the best idea is to form flanges or bends only with a radius that experience has shown will leave the bent sheet as strong as the original flat sheet.

Aluminum alloy of almost any thickness may be bent cold, provided you do it over a properly rounded corner. This curvature at the bend is referred to as the bend radius. It is the inside radius of the curve shown in figure 63.

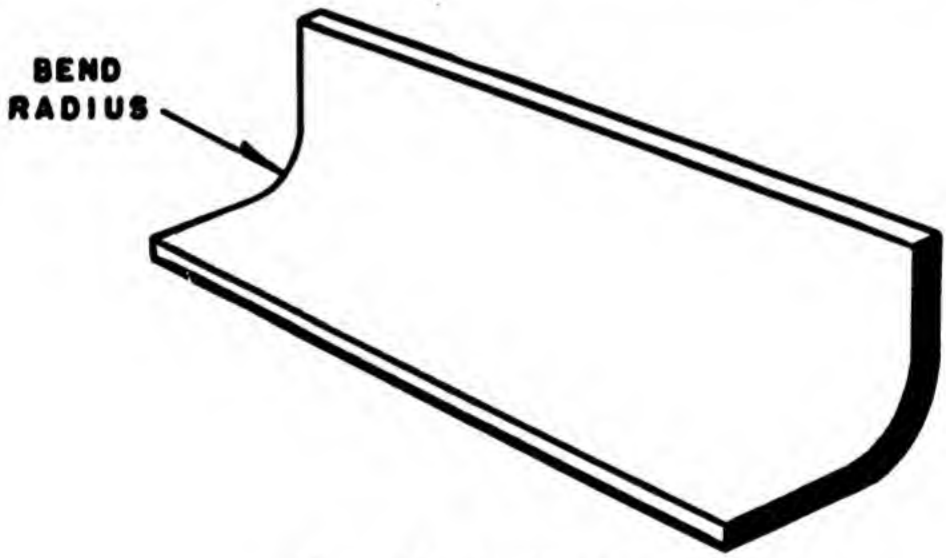


Figure 63.—Bend radius.

The required radius varies both with the grade and the thickness of the alloy. No exact value can be set up for the radius at which a sheet of a given material and thickness must be bent. There are, however, minimum radii which are generally accepted. They have been taken from the bend allowance table universally used in the aircraft industry, and some of these calculations are shown in Table I.

TABLE I

Radii Required for 90° Bends in Aluminum Alloy												
	Approximate Thickness											
Alloy	.020	.025	.028	.032	.040	.045	.051	.057	.064	.072	.081	.128
17SO..... 24SO.....	0	1/32	1/32	1/32	1/16	1/16	1/16	3/32	3/32	1/8	1/8	7/32
17ST. ...	1/32	1/16	1/16	1/16	3/32	1/8	1/8	5/32	5/32	5/32	1/4	5/16
24ST.....	3/32	1/8	1/8	1/8	5/32	3/16	3/16	3/16	3/16	7/32	5/16	1/2
24SRT...	3/32	1/8	1/8	1/8	5/32	3/16	3/16	1/4	1/4	9/32	7/16	5/8

After the flat pattern layout has been made, you can bend the metal with a cornice brake, bar folder, or form blocks. In each case, be sure the radius of the part over which you are bending the metal checks with your flat pattern calculations.

If you're using a cornice brake for this bending operation, radius bars will help you get accurate results. These are steel bars attached to the lower side of the clamping jaw of the cornice brake, as in figure 64 (*A*). They are machined to an exact thickness and radius, so that the bends they make will come out accordingly.

If you don't have any radius bars already made for

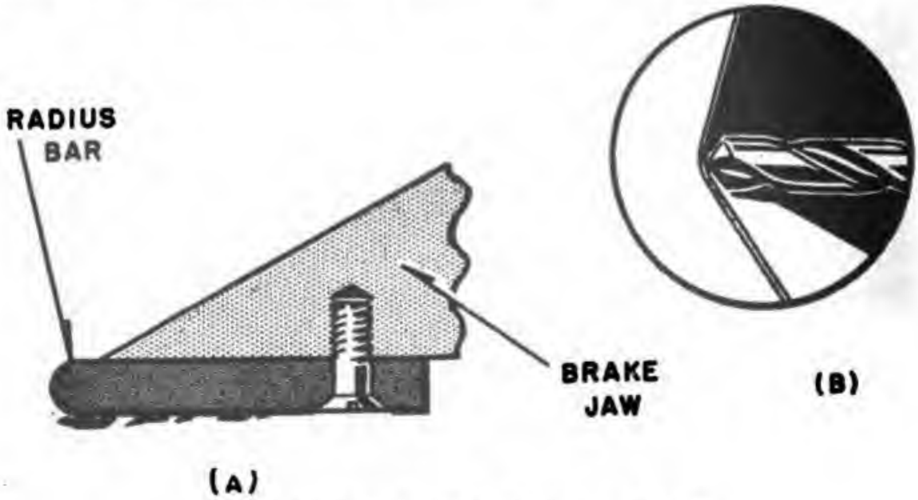


Figure 64.—Radius bar and check.

a desired radius, you can clamp pieces of sheet aluminum over the jaw of the brake, until the brake's nose has the radius you're after. When using this method, you can check for the accuracy of radius by inserting a rod of the right radius in a piece of alloy bent to the desired angle. Take a look at (*B*) of figure 64 to see this.

Be sure to adjust the jaws of the brake to provide enough clearance for the metal being bent. Otherwise,

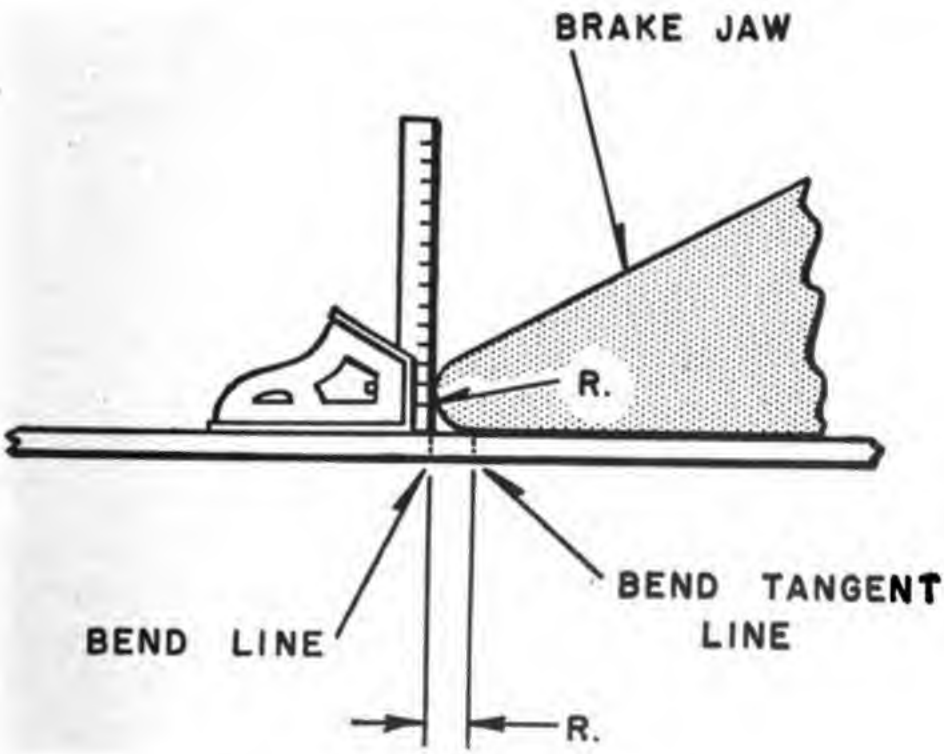


Figure 65.—Bend lines.

you may ruin the job by putting too much strain on the metal.

When you use a bar folder for bending operations, use extra pieces of metal to give you the right radius, or adjust the machine for a rounded bend. Form blocks automatically give the metal bent over them the radius to which the corner of the inner block has been shaped.

No matter which method of bending you use, the metal must be held so that the bend begins at what's

called the bend tangent line. Then, by "eye," or with a combination square, locate the bend line directly beneath the nose of the brake. This should be the length of the radius away from the bend tangent line. Take a look at figure 65 to get the relationship of these lines.

If you're using a folder, the bend line comes right at the edge of the folder blade. With form blocks of steel or wood, it should line up with the edge of the blocks.

One more thing. Bends must be made at an angle as near to 90 degrees as possible to the grain of the metal.

CHAPTER 3

RIVETING

KNOW YOUR ALUMINUM RIVETS

In case you never stopped to think about the RIVETS in an airplane, here's an eye opener. More than 150,000 rivets are required in the production of one medium bomber and nearly half a million in the production of one large bomber.

When the airplanes come limping in from combat, you're the doctor—you drive the rivets for repair. Each job you do requires a specific type of rivet. This includes not only the shape of the rivet head but also the kind of metal of which it is made—that is, whether it is made of aluminum or of aluminum alloy, and if an alloy, which one. So when you're selecting a rivet to do a certain job keep in mind the purpose for which the rivet is to be used.

Rivets consist of a solid shank capped with a head of one of various shapes. During the process of riveting, you form a head on the end of the shank opposite

the manufactured head. The process is known as "heading" the rivet.

The manufactured heads on AN (Army-Navy) standard aluminum and aluminum alloy rivets are of four basic shapes. They are identified by the code numbers shown in figure 66.

The BRAZIER HEAD rivet is used extensively for riveting thin sheet (skin) exposed to the slip stream. Such

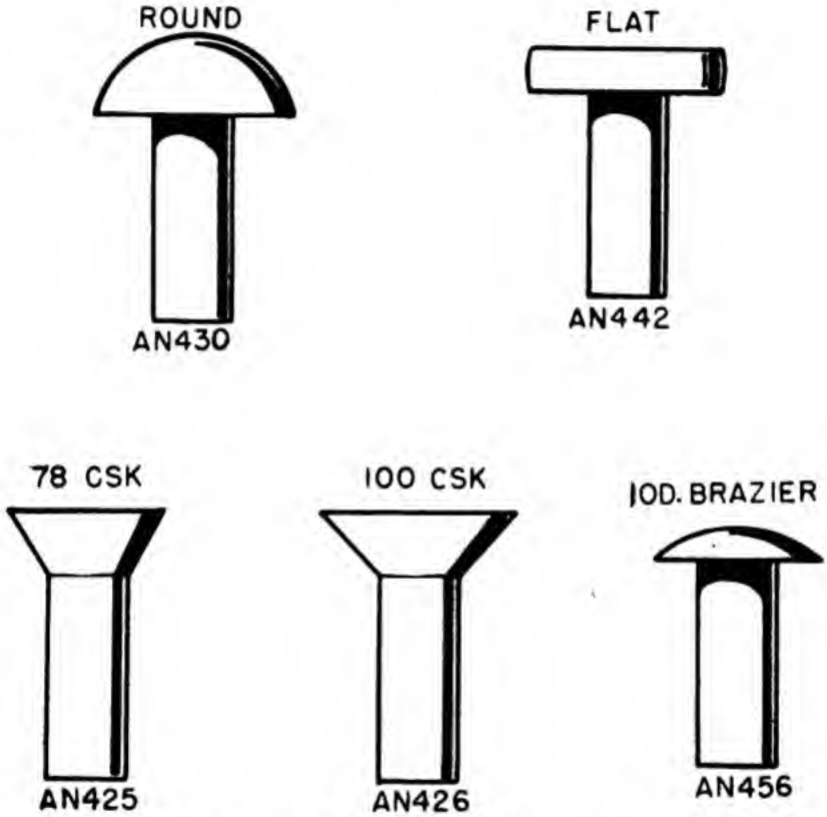


Figure 66.—Types of rivets.

a rivet has a low, rounding head which does not protrude much above the metal and thus offers little resistance to the air. The LARGE DIAMETER of the head makes it particularly adaptable for use in thin sections since it covers an area sufficient to strengthen the sheet around the hole. AN 456 (modified brazier head) rivets are used as replacements for AN 455 (brazier head) rivets in floats and hulls.

FLAT HEAD rivets are sometimes used on the inside

of aircraft structures where INCREASED CLEARANCE is necessary.

The ROUND HEAD rivet (AN 430) is used in relatively thick sheets where strength is required. The size of the head is such that it covers a sufficient area around the hole and at the same time offers considerable resistance tension. AN 430 and AN 442 (flat head rivets) are used inside the fuselage. AN 430 rivets are also used in tight places such as tail sections, because the head of the rivet holds the rivet set better than other rivet head shapes.

Countersunk rivets are used because they offer the least resistance to air flow. They are therefore used on many airplanes for external riveting of thin sheet metal which is exposed to the slip stream. In order to use this rivet head on thin sheet it is necessary to dimple (sometimes called "press countersinking") the sheet. Otherwise the countersunk plate will not be strong enough to support the head of the rivet. AN 426 (100° countersunk) rivets are usually used to secure the skin on combat planes. Countersunk rivets are also used to rivet thick sheets over which other plates must fit, because they don't protrude.

DOG TAGS FOR RIVETS

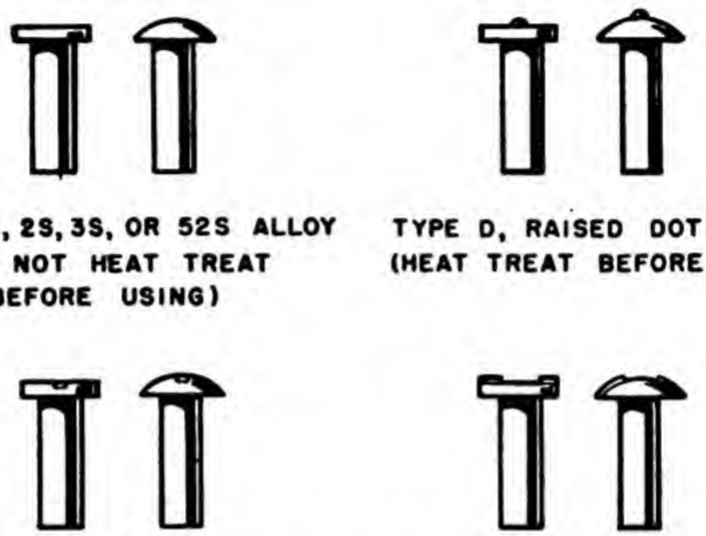
This discussion of rivets so far has dealt with head shapes. When you are selecting a rivet for a specific job, you can distinguish at a glance what shape of head it has. BUT aircraft rivets are made principally from four kinds of aluminum or aluminum alloy. How do you know which is which? To make their identification easy, aluminum manufacturers have "dog-tagged" the heads as shown in figure 67. ANY head shape may be ANY of the four alloy designations. For instance, a brazier head rivet could be a Type A, D, AD, or DD.

Notice that 2S and 3S rivets, type A, have a PLAIN HEAD WITHOUT MARKINGS. To distinguish between

the two, they are sometimes stamped "2," "3," or "5" on the END of the shank, denoting 2S, 3S, or 52S.

The 17S-T rivet, type D, has a bump or RAISED DOT on the center of the head for identification.

A DIMPLE in the center of its head identifies the A17S-T rivet, Type AD.



TYPE A, 2S, 3S, OR 52S ALLOY (DO NOT HEAT TREAT BEFORE USING)

TYPE D, RAISED DOT 17S-T (HEAT TREAT BEFORE USING)

TYPE AD, DIMPLE A17S-T (DO NOT HEAT TREAT BEFORE USING)

TYPE DD, RAISED BARS 24S-T (HEAT TREAT BEFORE USING)

Figure 67.—Alloy identification markings for rivets.

The 24S-T rivet, type DD, is identified by TWO RAISED BARS, or dashes, on opposite sides of the head.

A-N RIVET CODE

The Army and Navy has set up an AN Rivet Code, which you will be required to know in order to follow specifications for aircraft rivets on a blueprint or on other printed instructions. For example, suppose you received instructions to use an AN430AD-4-5 rivet to do a specific job. What does it mean?

The letters AN indicate Army-Navy specifications. The three digits, 430, tell you the head shape of the rivet. The two letters, AD, designate the alloy from which the rivet is made. A set of two dash numbers

(in this case, -4-5) tell you the diameter and the length of the rivet. The first dash number indicates the DIAMETER in 32nds of an inch and the second, the LENGTH in 16ths of an inch.

AN430AD-4-5——Length in 16ths
Diameter in 32nds
Alloy (A17S)
Head Shape (round)
Army-Navy

Note: Observe the position of the dashes in the example and be consistent in their use.

PICK THE RIGHT SIZE

Rivets come in various diameters and lengths. The most common rivet diameters are shown in Table II which also gives the sizes of drills to be used for the

TABLE II

DRILL SIZES FOR RIVETS

Rivet Shank Dia.	Drill No.	Drill Decimal
$\frac{1}{16}$	52	.0670
$\frac{3}{32}$	41	.0980
$\frac{1}{8}$	30	.1285
$\frac{5}{32}$	21	.1590
$\frac{3}{16}$	11	.1910
$\frac{1}{4}$	#F	.2570

various diameters of rivets. A drill from .002 to .004 inch LARGER than the rivet should be used for sheet and plate riveting.

There are three things you must remember in selecting the correct rivet for the job.

THE COMPOSITION OF THE RIVET.

ITS DIAMETER.

ITS LENGTH.

Selecting the rivet of the correct aluminum alloy is very important because, as you learned earlier, rivets carry shear stress. The full shear strength of a riveted joint depends upon the proper combination of material and rivet. If a hard rivet such as 17S is driven into a soft plate such as 2S-O or 3S-O, the result would be distortion of the sheet. In addition, you would lose completely the high shear strength value of the 17S rivet.

Authorities say that it is poor practice to drive a hard rivet into soft metal. But on the other hand, it may at times be advisable to use a soft rivet for hard material, especially if the joint is not subjected to unduly high stress. In general, however, the material in the rivet should possess the same properties as the metal it is to be driven into.

Table III is a handy guide for this purpose.

TABLE III

SELECTION OF RIVETS

Rivet Type	Use
A	Parts fabricated from 2S and 3S alloys
AD	Parts fabricated from 17S and 24S alloys
D	Parts fabricated from 17S and 24S alloys
DD	Parts fabricated from 24S alloy and as a substitute for types AD and D rivets.

The full strength of a riveted joint depends upon picking a rivet of the correct length and diameter.

If a large-diameter rivet were inserted in a thin sheet the pressure required to drive the rivet would result in bulging the thin metal around the rivet head. The accepted rule is to use a rivet whose diameter does not exceed 2½ to 3 times the thickness of the thickest sheet through which the rivet is driven as in figure 68.

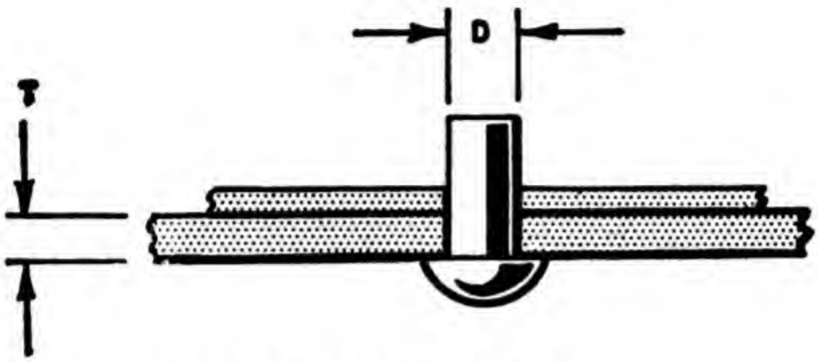


Figure 68.—Rivet diameter.

In any case, the rivet diameter should not be less than the thickness of the thickest plate through which it is driven. Rivets smaller than 3/32" in diameter should not be used for any structural parts which carry stress. On the other hand, very few rivets are used which are more than 5/16" in diameter.

It is also decidedly important that the rivet be of the correct length because a rivet that is too long has a tendency to bend when headed. On the other hand, a too-short rivet will prove too difficult to head and almost impossible to shape properly. The correct length of the rivet should equal the sum of the thickness of the metal plus 1½ times the diameter as in figure 69. The maximum length of the rivet shank before driving should not be more than 1.75D.

You also have to know what constitutes a properly headed rivet if you want to pass inspection. In other words, a rivet, to be effective, must be squashed within

certain limits. This can only be done if all the conditions mentioned earlier have been strictly followed—particularly the one in regard to the rivet length. In general, the height of the "bucktail" should equal ½ the diameter of the rivet. The minimum width of the

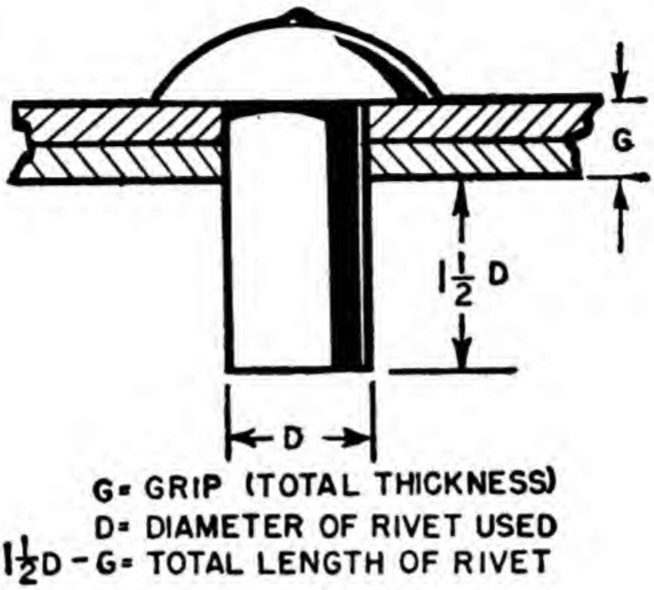


Figure 69.—Rivet length.

"bucktail" should be 1½ times the rivet diameter. For instance, a properly headed ⅛th inch rivet should extend a distance of 1/16th inch above the surface of

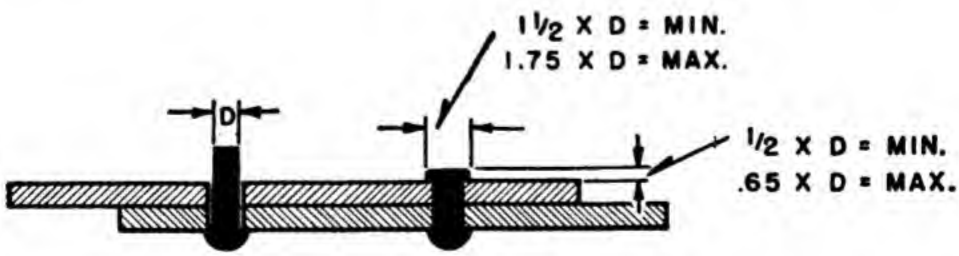


Figure 70.—A properly headed rivet.

the metal with the head approximately 3/16 inch across the flat. Figure 70 shows a before and after view of the heading process.

KEEP THEIR DISTANCE

Rivets should be spaced—

Like those in the original structure, if possible, and

Not less than a distance equal to three times the rivet diameter, and

Not more than a distance equal to twenty-four times the thickness of the thinnest sheet through which the rivet passes.

In practice, the center to center distance is usually from 4D to 8D, depending upon the requirements of the job at hand.

Rivets should be spaced in from the edge of the sheet

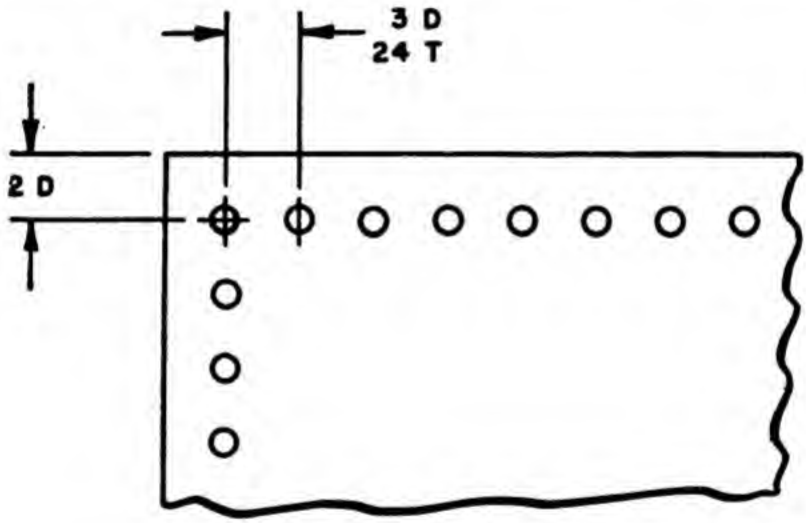


Figure 71.—Rivet spacing.

an absolute minimum of twice the rivet diameter. For countersunk rivets this distance must be 2½ times the diameter as in figure 71.

Here are some rules for riveting in general repair work.

The rivet size should be the same as that of the original rivets as far as possible, or larger.

The spacing should be kept the same as the spacing of the part being repaired unless closer spacing may be necessary.

Enough rivets must be installed to insure the strength of the parts to be joined.

TIPS ON ALUMINUM ALLOY RIVETS

As you probably realize, an Aviation Metalsmith's job in the field is often one continuous effort to "make do" with what he has on hand. Sometimes a rivet of a certain aluminum alloy can be substituted for a rivet of another alloy. Here are the rules for the selection and use of rivets made of the three common aluminum alloys, A17ST, 17ST and 24ST.

A17ST—May be used for general repair purposes, including floats and hulls, provided the following restrictions are observed.

- They shall be used SIZE FOR SIZE where they are specified in the manufacturer's drawings.
- They may be used INSTEAD OF specified 17ST rivets if the next larger size rivet is used and if edge distances are maintained.
- They can be used when it is necessary to drill existing rivet holes OVERSIZE because of elongation of the hole.
- A17ST rivets are inferior to 17ST rivets in strength and corrosion resistance.
- The Bureau of Aeronautics has authorized the use of all A17ST rivets except on floats and hulls made of non-clad 24ST material. On such material the use of 17ST and 24ST rivets is still required.

17ST—May be used to replace 24ST rivets provided the next larger size is used and provided edge distances are adequate.

- You must be sure to adhere strictly to heat-treatment procedures and to the rules for usage after heat-treatment.

24ST—These rivets are used only when required or by written engineering instructions.

REPLACEMENT OF RIVETS

Sometimes you will be called upon to replace rivets in certain installations. The Bureau of Aeronautics, in a recent Technical Order, indicates the recommended procedure to follow. It says—

"In the replacement of rivets in those installations which require rivet heads having a flat underface or flat bearing surface, all activities are requested to use whichever of rivets AN430, AN442, and AN456 that corresponds to the type of rivet removed.

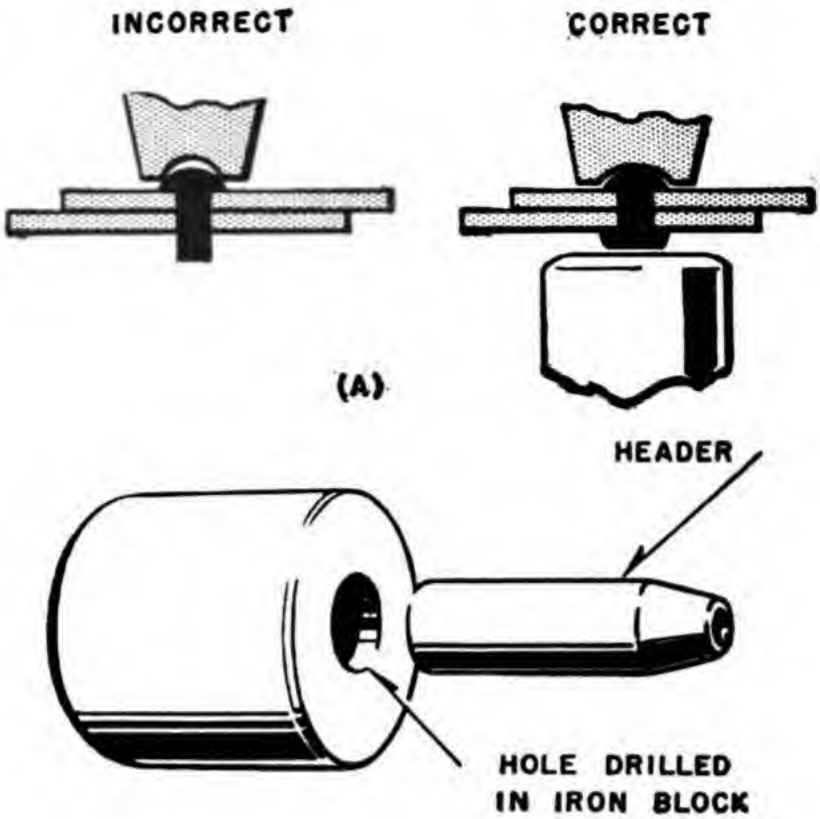
"Thus, all round head rivets will be replaced by AN430 rivets; all flat head rivets by AN442 rivets; and all brazier head rivets by AN456 rivets. Countersunk head rivets are to be replaced by rivets of the same type and degree of countersunk head, and of a size larger if necessary, as when the rivet hole has become enlarged, deformed, or otherwise damaged."

HAND RIVETING

To do hand riveting you need two tools—a hammer and bucking block. The bucking block is held against the rivet head while you strike the end of the rivet with the face of the hammer.

A medium weight ball-peen hammer or a riveting hammer may be used. Don't try to use too heavy a hammer because it tends to stretch the metal too much, while one that is too light requires you to use too many blows. This means that the rivet will strain-harden rapidly.

The bucking block should have a cup-like depression in the end to take care of the rivet head. The depression should be slightly shallower and also wider than the head of the rivet in order not to distort it. Figure 72(*A*) shows correct and incorrect shapes for this cup-like depression. A rivet header like that used on pneumatic riveters makes a very good bucking bar for hand



(B)

Figure 72.—Bucking blocks.

riveting if you support it in a steel block. Any piece of steel or cast iron is OK. Simply drill a hole in the metal and stick the shank of the header into it, as in figure 72(*B*).

HOW'S YOUR TECHNIQUE?

The first step in hand riveting is of course to drill a hole for the rivet. The hole must be of the right size. This is important because if the openings are too small, the rivets must be forced through. Forcing leaves tiny grooves on the shanks of rivets which materially affect their strength. There is also a tendency to buckle the metal. On the other hand, large holes are objectionable, because the shanks of the rivets are liable to bend during the heading operations. A series of holes that are too large will permit the sheet to shift out of alinement.

After the holes have been drilled, remove all burrs by filing them off or by using a reamer or countersink. A drill slightly larger than the hole is sometimes used to file off these burrs as in (*A*) of figure 73.

As an extra precaution against marring the heads of rivets put a small piece of masking tape inside the cup of the bucking block.

Decide on the diameter and length of the rivet you will use.

Now, place the section of metal to be riveted over the bucking block with the rivet head resting in the cup, as in figure 73(*B*.) If the riveting is to be done on a structural piece, a separate rivet set and bucking bar must be used like that in figure 73(*C*).

Strike the end of the rivet with the face of the hammer and make sure that each blow hits the rivet shank squarely. After striking the rivet a few times stop and check the bucked end.

DRILLING OUT A RIVET

Occasionally you will be confronted with the job of

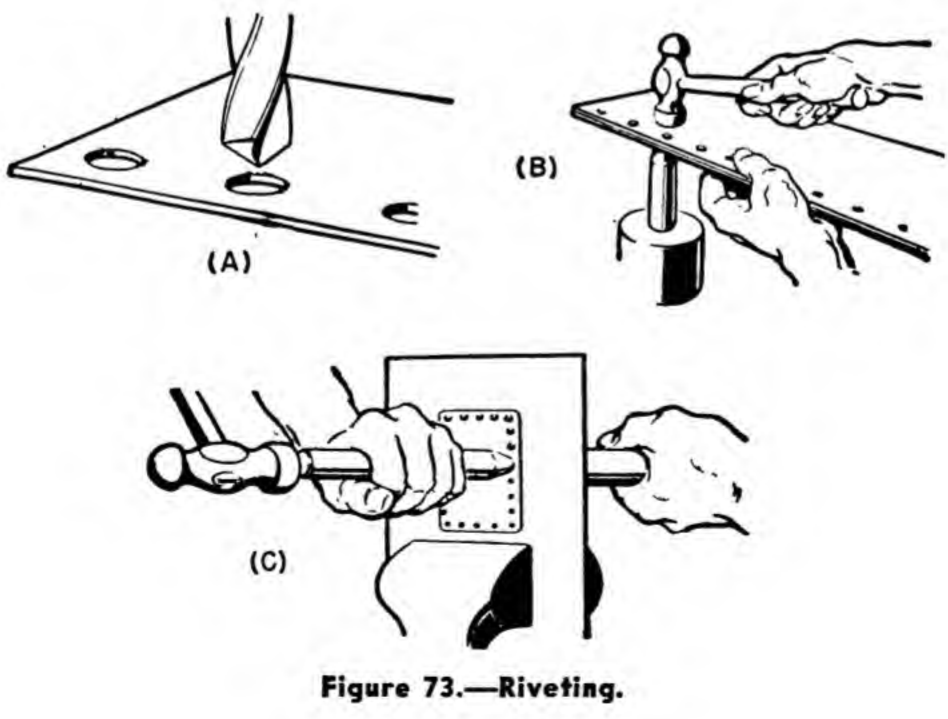


Figure 73.—Riveting.

removing rivets from an aluminum surface. Although the task is really simple, you must take a few precautions to avoid ruining the section.

Here's how.

Lightly center punch the heads of the rivets as in (*A*) of figure 74.

Pick a drill that is slightly smaller in size than the shank of the rivet.

Now, drill through the head of the rivet only as in (*B*). If you run the drill through the entire rivet, you take a chance on cutting into the sheet.

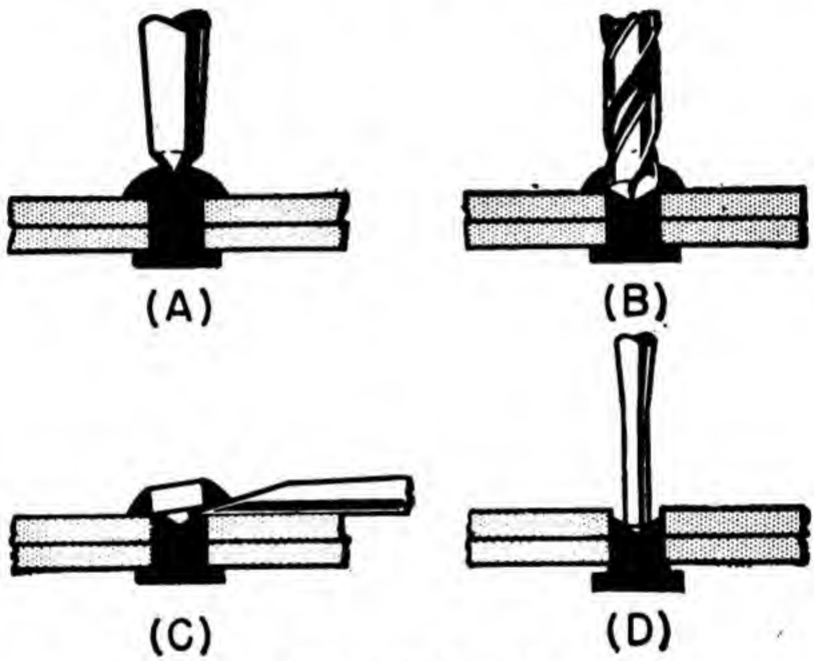


Figure 74.—Drilling out a rivet.

Next, knock off the drill heads with a cold chisel as in (*C*). To keep the chisel from marring the surface of the metal, its cutting edge should be slightly rounded.

Finally, drive out the remaining part of the rivet as in (*D*), with a pin punch.

PNEUMATIC RIVETING

Often instead of riveting by hand you will use a pneu-

matic riveter. There are four common kinds. These are the slow hitting, fast hitting, one shot, and compression or squeeze types.

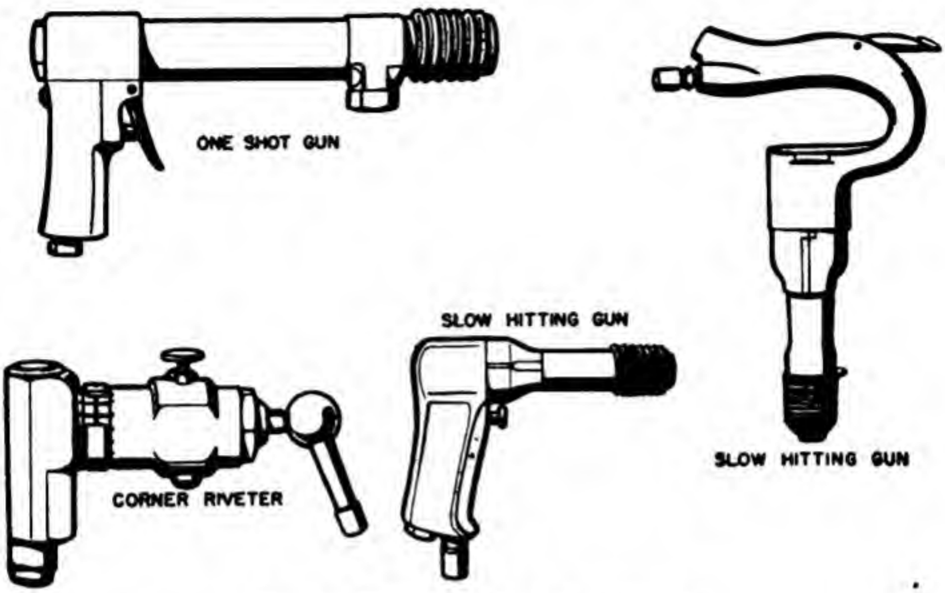


Figure 75.—Riveting hammers.

Slow hitting riveting hammers have a speed up to approximately 2500 B.P.M. (blows per minute). The fast hitting hammers range from 2500 up to 5000 B.P.M. These slow and fast hitting hammers come in various shapes and sizes for the different types of repair work you'll have to do. Some of them are shown in figure 75.

One shot riveting hammers are generally larger than either slow or fast hitting hammers. As you can guess from the name, the valve mechanism is designed so that each time you pull the trigger a rivet is headed with one blow. Figure 75 shows a one shot hammer.

Pneumatic squeeze riveters range in size from the small portable to the large stationary types. Some portable squeeze riveters are shown in figure 76. They have interchangeable rivet sets so that all sorts of rivets may be driven. When you pull the trigger, the bucking bar (flat set) moves forward on one side and bucks the head with a direct squeezing action against a rivet

set of the proper head type on the other side of the jaw.

These sets can be adjusted so that you can drive different size rivets to the proper heights. One work-

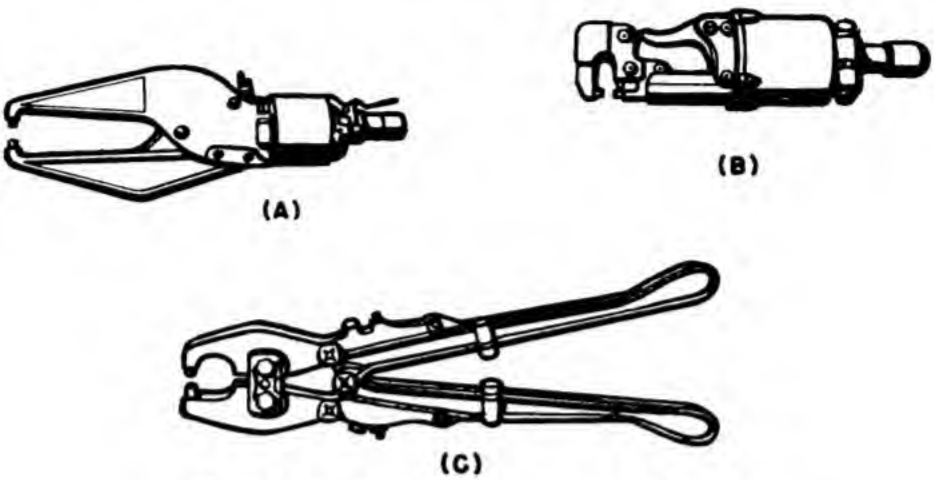


Figure 76.—Portable squeeze riveters.

saving feature of the squeeze riveter is that after it is set, all of the rivets will be driven in a uniform manner.

HOW TO CHOOSE THE RIGHT GUN

You decide upon which gun to use by taking into account the size and the type of alloy of which the rivets are made, and in addition, the accessibility of the place into which the rivets are to be driven.

For instance, if you want to drive medium-size, heat-treated rivets which are in accessible places, the slow hitting rivet gun is your dish.

For small, soft alloy rivets you should use a fast hitting gun. What would you do if you had to drive medium-size rivets in a corner? Obviously, you couldn't use a conventional type of gun. Instead, you would choose a corner gun, or one having an offset rivet set. A corner riveter is shown in figure 75.

For heavier riveting, use a one shot riveter. While under certain conditions this kind of gun is the fastest means of riveting, you cannot use it on thin metal because it is too difficult to control.

A squeeze riveter should be used on the trailing edges, wing root sections, and along those edges where the yoke of this type of gun will fit. Figure 77 shows such a condition.

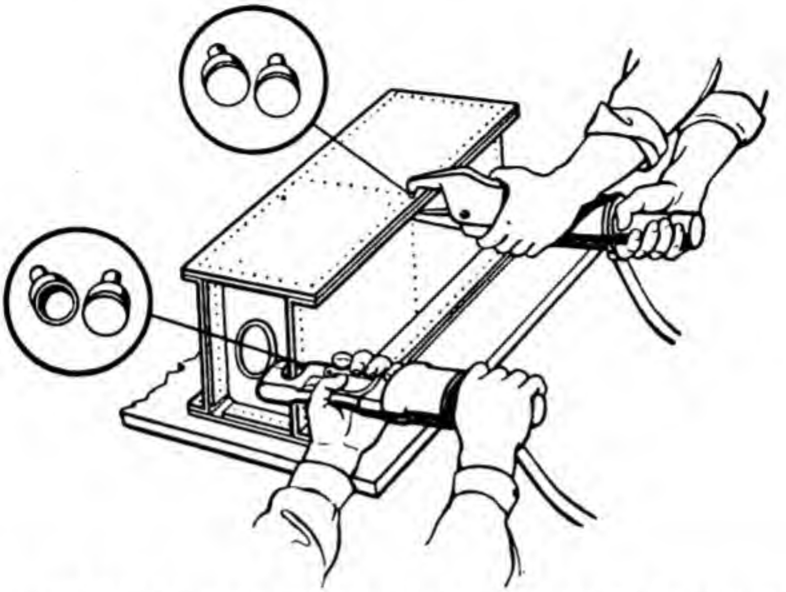


Figure 77.—Riveting with portable pneumatic squeezers.

Here is a table which lists the approximate air pressures for rivet guns according to the size of rivet which is to be driven.

APPROXIMATE AIR PRESSURE FOR RIVET GUNS

Rivet Size	Pounds per Sq. In.
3/32	25
1/8	40
5/32	60
3/16	90

You will usually have no one to blame but yourself if your rivet gun becomes injured. Carelessness is the greatest cause of damage to rivet guns. If you drop it, a number of bad things happen. You may find your gun has a cracked handle, a damaged barrel, or a broken trigger, air inlet, or adjusting sleeve.

As in the case of most tools or machines which have movable parts, you will find that your rivet gun wears out, unless you take good care of it. Rivet guns should have a systematic cleaning in a mixture of kerosene and oil at least once a month. They should be regularly oiled.

Where guns are in constant use, this procedure for oiling at the cylinder and piston should be followed daily—

Invert the gun and inject a small amount of light high grade machine oil into the air inlet.

Attach the hose.

Allow the gun to operate for about five seconds as you hold the set against a block of soft material.

Never allow a gun to be operated without a set in it. And always be sure the set is held against a rivet or a soft solid object such as a block of wood.

Sometimes the handle becomes loose on the barrels. Look out for this and always tighten it to prevent injury both to yourself and to the gun.

Always check your air inlet and hose fittings to see that they are free from foreign particles which might be blown into the mechanism of the gun.

Most guns have an adjustable sleeve which regulates their speed and force. Always check this sleeve to see that the pressure is not too great. In no case should the sleeve be loosened so that the adjusting pin sticks out beyond it.

You must have clean air to operate a pneumatic riveting gun if you want to avoid trouble. In most cases, the compressor of the gun is equipped with dirt

strainers and water traps in the compressor lines. Check the strainers and water traps often, and keep them clean.

The air compressor should be equipped with a pressure valve set so that an excess of air pressure will never be allowed on the hose or the gun. The usual pressure is approximately 90 to 100 pounds.

When you pull the trigger on a pneumatic riveter, the compressed air forces the piston in the cylinder back and forth with great rapidity. The impact of the piston is passed along to the rivet through the rivet set, or die, which is fitted by means of a retaining spring into the nose of the gun.

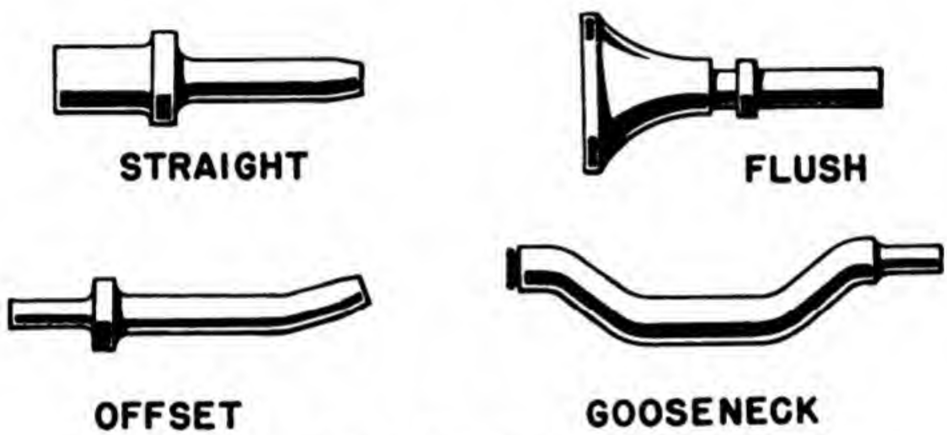


Figure 78.—Rivet sets

The tips of these rivet sets are made to fit the manufactured head of the rivet.

For flush riveting you use a rivet set with a flat face or slightly crowned face.

Keep your dies in good condition—highly polished and free from nicks or scratches. Never test the air pressure of your riveter by putting a rivet set against a steel or solid object. Use instead a soft wood block which is clean and has no dirt or metal particles to mar the rivet set.

Rivet sets are shown in figure 78. They are made in a variety of sizes and shapes. In many places where rivets can't be reached with a straight set, or with a corner gun, you will use an offset, or angular set.

Rivet sets or dies used for the same size rivet are made in several different lengths. The choice of the proper length to use depends upon the driving condi-

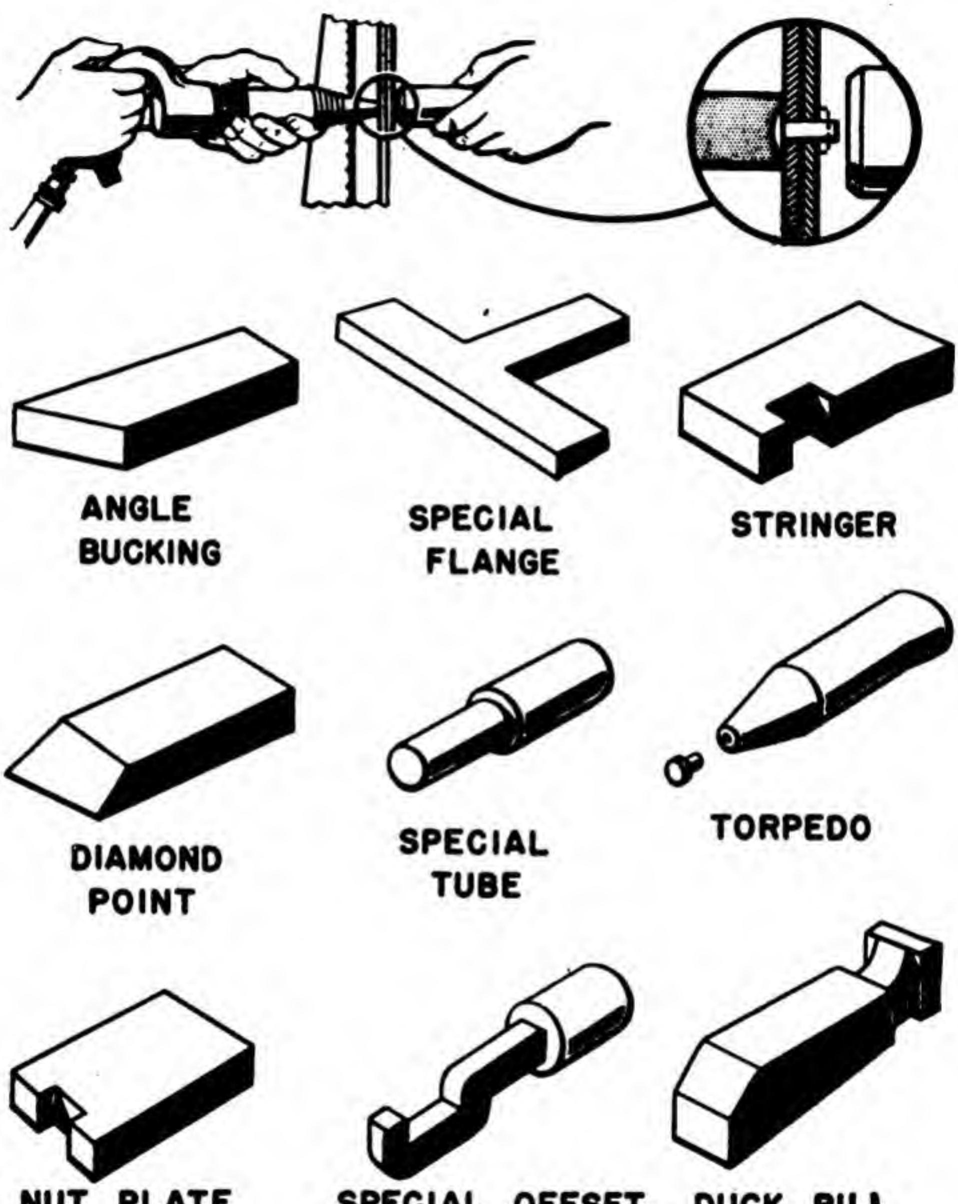


Figure 79.—Bucking bars.

tions. When it is possible to get the gun close to the work, use a short, straight set since it is most efficient. When structural interferences prevent you from getting close to the work, longer sets should be used.

BUCKING BARS

When riveting with the pneumatic riveter, you'll find it best to work with a partner. The gunner operates the riveter while the bucker "bucks" up the rivet by holding a bucking dolly or bucking bar against the rivet shank on the opposite side of the parts to be riveted. Figure 79 illustrates team riveting.

The bucker is as important in team riveting as the blocker in football. Usually his job is more difficult than that of the gunner, since he often has to squirm around in cramped quarters to hold the bucking bar correctly against the rivet.

Bucking bars are usually made of tool steel. They should be heavy enough to buck the rivet solidly, yet light enough to be conveniently handled when bucking. Actually the size, shape and weight of the bar will be determined by the size, kind, and location of the rivets being bucked. In figure 79 you see several types of bucking bars, and, in figure 80, examples of bars used in various locations. Where you run into obstructions, or when you must work in places where a plain bucking bar won't do, you may have to make up special bars.

If you follow the following procedure carefully, you should do a good job.

First select a rivet gun which is right for the job. Be sure that the air line is free from dirt or lint and that it is securely fastened before you open the valve.

Then pick a rivet set which has the correct head for the rivet to be used. Check to see that the shank of the rivet set will fit into the gun.

Now fit the rivet set into the gun.

> Warning—Be sure the retaining spring is in place. If it isn't, the set might be thrown from the gun if the trigger is pressed accidentally.

Even though a modern airplane has hundreds of thousands of rivets, each rivet has an important function and will bear a definite amount of stress. If one

rivet fails, there is an added burden on the next one, and on the next, and so forth. A whole line of rivets may start popping and result in structural failure.

Drive every rivet perfectly in order to be sure you have a good, sound structure with uniform strength.

Put the rivet set against a block of soft, clean wood and adjust the speed of the gun to suit the job. (You'll

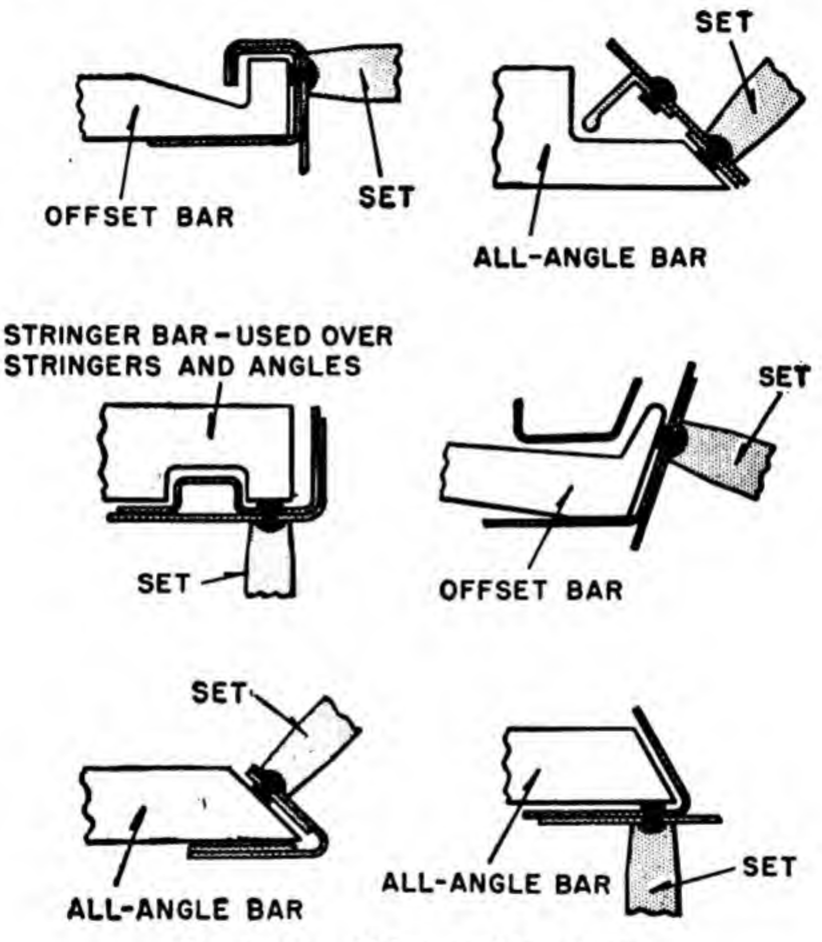


Figure 80.—Using bucking bars.

get to know the right speed for different conditions as you gain experience.) Try driving a few experimental rivets in some scrap aluminum before you attempt to rivet the actual part.

Now you're ready to go.

Press the gun set (the gun with rivet set fitted into it) firmly against the rivet head. Be sure to hold the gun and set at right angles to the material. In this way,

you avoid marking the rivet head or leaving a ring or dent on the surrounding metal.

The bucking bar must also be held in the right angle position shown in the inset of figure 79. It is placed squarely on the rivet shank. Never operate the rivet gun until your partner with the bucking bar gives you the go sign. And always be sure that the rivet gun is completely through operating before either the gun or bucking bar is taken away. Otherwise, both heads and shanks of the rivet and both sides of the skin may be spoiled.

The bucking bar must be held firmly—no shifting around. Faulty rivets are the result of permitting the bar to wobble.

If the job you're working on requires you to draw the piece of metal together before you start riveting, put the bucking bar against the metal alongside of the rivet's shank. Then give the bar a short burst from the gun. This trick will draw the two pieces together enough to permit you to drive the rivet.

You will have to devise and adopt a system of signaling to be used between you and the bucker. This is particularly important when the bucker is inside a structure and the gunner is outside. In a typical system of team work, the gunner places the gun set on the rivet head. The bucker gives one tap on the rivet shank to indicate that he is ready. The rivet is then upset with one "burst" by the riveting gun. Then, if an extra short burst is necessary to complete the riveting the bucker taps once again. Two taps by the bucker indicate that the rivet is satisfactory. Three taps mean "take out and replace."

Always check the rivets to make certain they are driven to the proper specifications.

HEAT-TREATING RIVETS

Strength is an all-important factor in the construction of aircraft. And strength is one of the two qualities

which heat-treating adds to rivets. Because an airplane is held together principally by rivets, it is absolutely necessary that you know when and where to use heat-treated rivets or those that do not require heat-treatment. And what's more, you have to know how to heat-treat rivets and how to take care of them so that you get the maximum benefit from their particular physical qualities. You can get some idea of the difference in strength between heat-treated and nonheat-treated rivets from the Table IV. Compare the shearing and tensile strength of a 2S-H rivet and a 24ST rivet.

TABLE IV

COMPARISON OF STRENGTH OF RIVETS

Type of Rivet	Yield Strength Psi	Shear Strength Psi	Ultimate Tensile Strength Psi
2S-H	21,000	13,000	24,000
3S-H	25,000	16,000	29,000
A17ST	18,500	25,000	38,000
17ST	32,000	30,000	55,000
24ST	40,000	35,000	62,000

As you can see from Table IV, 2S-H rivets (these are not heat-treated) have a shearing strength of 13,000 pounds psi and a tensile strength of 24,000 pounds psi. Alloy 24ST rivets (these are heat-treated) on the other hand, have almost three times the shearing strength—35,000 pounds. Their tensile strength is 62,000 pounds. Thus you see that 24ST rivets are almost three times stronger—a very important factor. It's easy to see what would happen to an airplane held together with

2S-H rivets when 24ST rivets should have been used.

As you learned earlier, there are two general groups of rivets. Those which can be used without being heat-treated, are types A and AD rivets. Those which must be heat-treated before they can be used are D and DD rivets. In addition to developing the maximum strength of the alloy, heat-treatment of 17S and 24S alloyed rivets also makes them soft so that they can be driven.

The most important thing to remember in getting together the equipment for heat-treating rivets is that the success of your job depends directly upon temperature control. If you overheat the rivets, they begin to disintegrate or break down. If they are not heated enough, you might as well have saved your strength. The treatment has no effect.

Rivets can be heated in either of two ways.

In a bath of sodium nitrate.

In a hot air furnace.

The sodium nitrate bath is the most common method.

SALT BATHS FOR RIVETS

The design of the sodium nitrate baths for heat-treating rivets should be such that the rivets do not come into contact with molten salt.

This equipment usually consists of a round tank or pot installed in a vertical electric furnace. The inside of the tank is fitted with a number of liquid-tight, vertical metal tubes, which keep the molten salt out. The clearance between these metal tubes should be at least ¼ of an inch in order to permit the salt bath to circulate freely around their outside surfaces. These tubes are about 2 inches to 2½ inches in diameter. They are closed at the bottom but are let open at the top so that you can slip into them the individual rivet containers.

The top of the tank has a cover plate through which the tops of the metal tubes stick out. Figure 108 shows you the tank and some of the parts which are described here. A close fitting, insulated door covers the entire

top of the tank and tubes. Thus for all practical purposes this kind of salt bath equipment is simply an air furnace in which the heat is supplied by the molten salt.

In order to make it easy for you to transfer hot rivets from the salt bath to the quenching bath, you will need

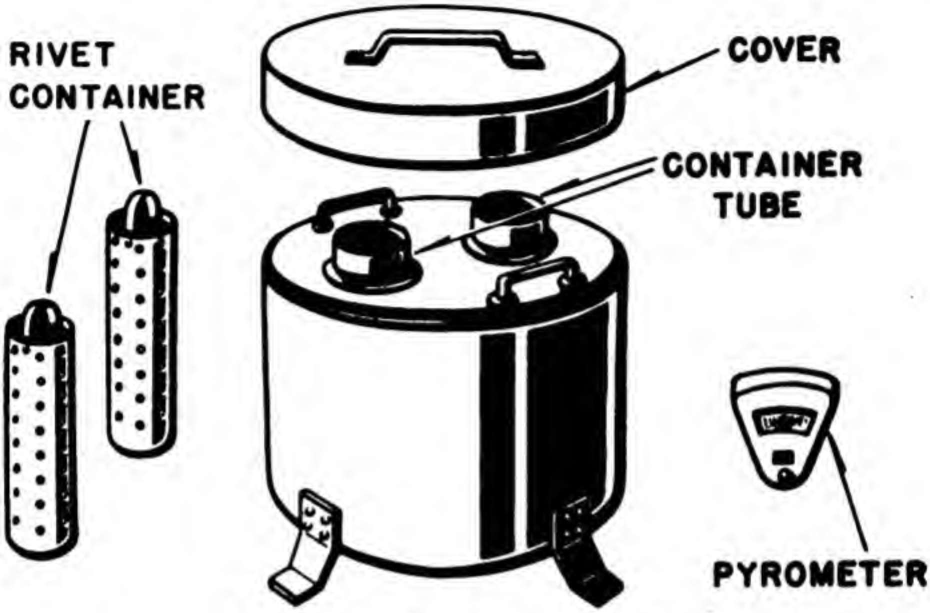


Figure 81.—Salt bath for rivets.

perforated containers which will fit into the vertical tubes of the tank. These rivet containers should be short enough so that their tops are at least four inches below the surface of the salt bath.

You will also need a pyrometer to eliminate all guess work concerning the temperature of the rivet bath. The pyrometer should be of the automatic controlling and recording type—preferably the potentiometer type. You should also use a thermocouple designed for salt baths. Insert it into the bath in a suitable protective tube.

TRY A BATCH

Put the rivets in the heat furnace and allow them to "soak." Soaking means holding the rivets of a given alloy at a certain temperature for a specified length of time to insure an even distribution of heat. 17S rivets

should be soaked at a temperature of 925° F. to 950° F. Rivets of 24S alloy should be soaked at a temperature of 910° F. to 930° F.

The time you soak them depends on a number of things. It depends upon the type of alloy, the diameter of the rivet and the type of equipment you are using—and also whether or not the equipment is efficient.

In general you should figure out by experimenting a little what length of time is best to produce the desired results with the equipment you have on hand.

For the salt bath equipment which has just been described, or for air furnaces provided with mechanical recirculation of air, you should not soak the rivets less than 10 minutes. This soaking time does not apply, however, to the 24S rivets.

The soaking time for 24S rivets should not be less than 30 minutes, leaving out the time it takes the batch of rivets to reach the specified temperature. You can determine this time by placing a thermocouple within or near the bath. ("Charge" is the technical term for the number of rivets heat-treated in any one operation.) Use the thermocouple to determine the time for each size and arrangement of charge which you normally employ.

After you have soaked the rivets for the specified length of time, remove the rivet container from the furnace and dunk the rivets in cold water within 10 seconds. This is called quenching.

If you fail to quench the rivets immediately they will lose their corrosion resistance, the softened quality which makes them easy to drive, and their ultimate tensile strength. See that you have enough quenching water on hand to avoid any appreciable rise in termperature during quenching.

STORING HEAT-TREATED RIVETS

Heat-treated rivets start to age harden as soon as they are removed from the quenching bath. Age harden-

ing is the automatic return to hardness of the alloy in the rivet following heat-treatment. It occurs spontaneously at room temperature and is very rapid during the first 24 hours. Age hardening is considered complete at the end of 4 days.

Therefore unless you put the rivets in a refrigerator or pack them in dry ice, you must drive them almost immediately. Rivets made of 17ST alloy must be driven within one hour after quenching unless they are kept at 32° F., in which case they can be driven after one day in such storage. If they are stored in dry ice or a refrigerator below 32° F. they can be driven within one week.

Rivets of 24ST must be driven within ½ hour, preferably 10 minutes after they have been quenched. If they were packed in dry ice following quenching, they may be driven within a twenty-four hour period.

Once you take rivets from a refrigerator, do not return them. Instead place them in their proper storage place from where they may be re-heat-treated. As a general rule, you can heat-treat rivets over and over again as often as you want to providing the heat-treatment is properly and carefully done. An excessive number of re-heatings will result in the gradual hardening of the rivets. How much is "excessive"? More than 15 times.

FLUSH RIVETING

In view of the great demand for increased speed of all combat aircraft, engineers have overcome drag wherever possible by using flush rivets on exterior surfaces subject to airflow or, in the case of flying boats, subject to water on the bottom. This method of riveting is also used where one part must be fitted over another without the interference of protruding rivet heads. Since flush rivets are made with angles varying from 78 to 100 degrees it is necessary to countersink or dimple the metal to the angle of the rivet being used. Most of

your work will be done with the 100 degree angle flush rivet. All countersinking and dimpling must be done with extreme care to avoid having wrinkles show up in the finished job.

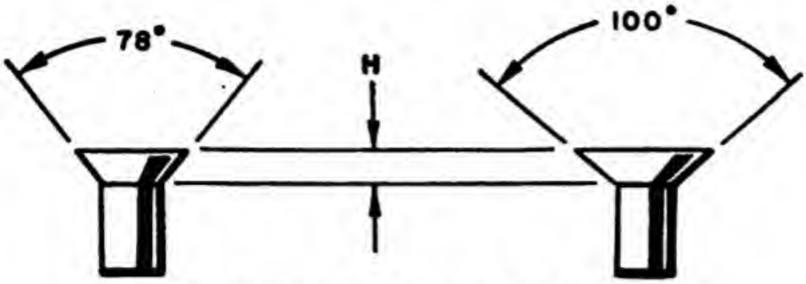


Figure 82.—Flush rivets.

PREPARE THE SHEET

The process you use in preparing the sheet you use for flush riveting depends upon its thickness. Look at Table V. Here you find the general recommendations on which method to use.

TABLE V

METHODS FOR COUNTERSINKING

Rivet Dia.	Top Sheet (t)	Under Sheet (t)	Countersink (See code)
3/32"	.032 or greater		A
3/32"	.025 or less	.051 or greater	B
3/32"	.025 or less	.040 or less	C
1/8"	.040 or greater		A
1/8"	.032 or less	.064 or greater	B
1/8"	.032 or less	.051 or less	C
5/32"	.051 or greater		A
5/32"	.040 or less	.072 or greater	B
5/32"	.040 or less	.064 or less	C
3/16"	.064 or greater		A
3/16"	.051 or less	.091 or greater	B
3/16"	.051 or less	.081 or less	C

Here is the code.

A—Machine countersink (cut) top sheet.

B—Press countersink (dimple) top sheet and machine countersink under sheet (or sheets).

C—Press countersink (dimple) top and under sheets.

DIMPLING

Dimpling is done by pressing the metal around the rivet hole to the proper shape by using dies. Since there are different angles of countersunk rivet heads, there must be a special set of dies for each angle as well as for each size of rivet.

The most common practice today is to use either a 78° or a 100° countersunk rivet. The 100° countersunk rivet is the standard. In repair work you'll be required to replace rivets whose degree of countersink is less than 78° with a 78° rivet. Rivets greater than 78° should be replaced with the standard 100° rivet. Obviously this means that you will have to re-dimple or re-countersink the hole to take care of the new rivet. But you must not substitute a machine countersunk hole for a previously dimpled hole.

Dimpling dies are made in sets of two pieces as in figure 83. One piece is known as the female, and the other, the male part. The angle cut in the female and male dies is 96° for use with the 100° head rivet. The pin diameters of the male dies are as follows.

3/32 in. rivets	.091 in.
1/8 in. rivets	.123 in.
5/32 in. rivets	.154 in.
3/16 in. rivets	.185 in.

The holes in the corresponding female dies are .002 in. larger in diameter than the pin of the male dies.

When you don't have the appropriate tools on hand, you can use a rivet for the male die and a block for the female die. This block should have the correct size hole and of course the correct angle of countersinking.

In dimpling, you pre-drill the rivet hole smaller than

the rivet used, because the hole will be enlarged in the dimpling process.

Dimpling dies for light work can be set up in a portable pneumatic or hand squeezers as in (*A*) of figure 83. For repair work, the dies can be held by hand as in (*B*). If the dies are used with a squeezer,

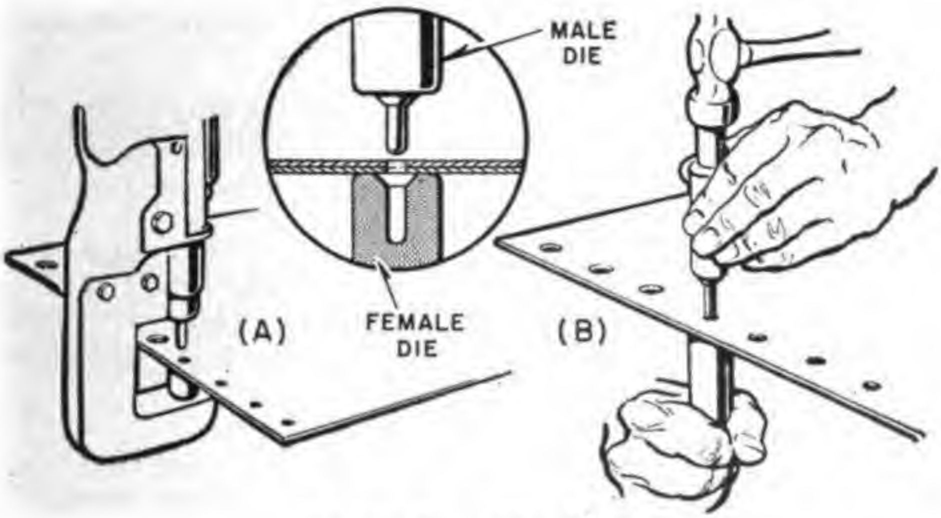


Figure 83.—Dimpling.

they must, of course, be adjusted accurately to the thickness of the sheet being dimpled.

CUT COUNTERSINKING

For cut countersinking, pre-drill the rivet holes to rivet size and then countersink. The best tool for cut countersinking is the one shown in figure 84. This is a stop type of countersink. It has the included angle stamped on the cover. The 78° and 100° angle countersinks are used, naturally, with their respective rivets.

The countersink should always be equipped with the fiber collar shown in figure 84, to prevent it from marring the aluminum. Carefully adjust and test your countersink on a piece of scrap metal to be sure that the rivet will fit into the hole which is cut flush with the surface of the metal.

If the under piece of metal is cut countersunk and

the outer sheet is dimpled, test the two operations on scrap of the same thickness. The rivets should fit flush and the dimple sheet should fit well into the countersunk sheet.

A countersink such as the one just described is operated by a hand, air, or electric drill, which should

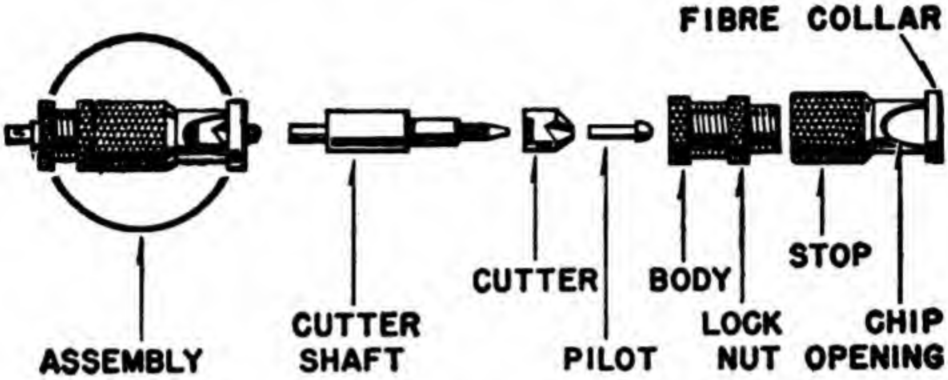


Figure 84.—Stop type countersink.

operate below 2500 rpm. The countersink must be sharp to avoid the vibration and chatter which result in imperfect holes. Figure 85 shows some of the things that can happen when you do an incorrect job of countersinking. The shaft of the countersink should be well lubricated with light oil and graphite at all times.

Machine countersinking refers to cutting the metal with a countersink. Press countersinking means dimpling the sheet to the shape of the rivet head. In some work, both dimpling and machine countersinking are used.

Now that you have learned something about the preparation of holes for flush riveting, you're ready to go ahead and do the riveting. Equipment for flush riveting is the same as any other except that the rivet sets are either flat faced or slightly arched, because of course you want to drive a rivet which will not protrude above the surface of the metal. There are two types of such rivet sets. One is known as the mushroom set; the other, the swivel set. The mushroom set is made in one piece. The swivel has a large face and is made

with a ball joint which is surrounded by a rubber sleeve to prevent marring the aluminum and also to prevent the tool from slipping.

You'll have to be considerably more careful in driving and bucking flush rivets than ordinary rivets. You and the bucker must in most cases use the signals you have figured out in order to know when the rivet is driven sufficiently.

You and your partner must each regulate the pressure which you apply on the gun and against the bucking bar respectively, so that the skin is not stretched. You don't want to produce a bulge in the sheet. Be

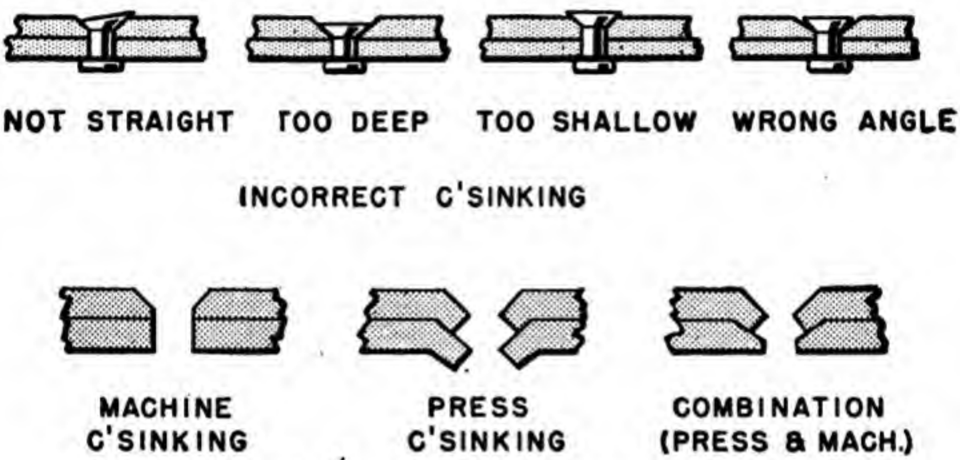


Figure 85.—Countersinking.

careful to hold the rivet set flat against the rivet to avoid nicking and marking up the skin. The actual driving of the rivet is similar to that used for ordinary rivets.

CHERRY RIVETS

Now here comes a different kind of rivet. In fact, technically speaking, it would be considered a fastener. But it is CALLED a rivet, so it is included in this chapter on rivets, rather than the one on fasteners, which follows.

The big feature of a cherry rivet is that it can be expanded from the OUTSIDE. Thus a bucking bar isn't necessary. One man can install cherry rivets. Ob-

viously, they are handy for use as permanent fasteners on the surfaces of aircraft which can be reached from only one side.

How does a cherry rivet work? It is made in two parts. The rivet itself which has a hole through the shank and head is made of A17ST alloy. The stem or mandrel is made of 17ST alloy.

The two parts are assembled at the factory and come to you ready for use. As you can see from figure 86, the stem extends beyond the rivet in each direction and has a pre-formed head on either end.

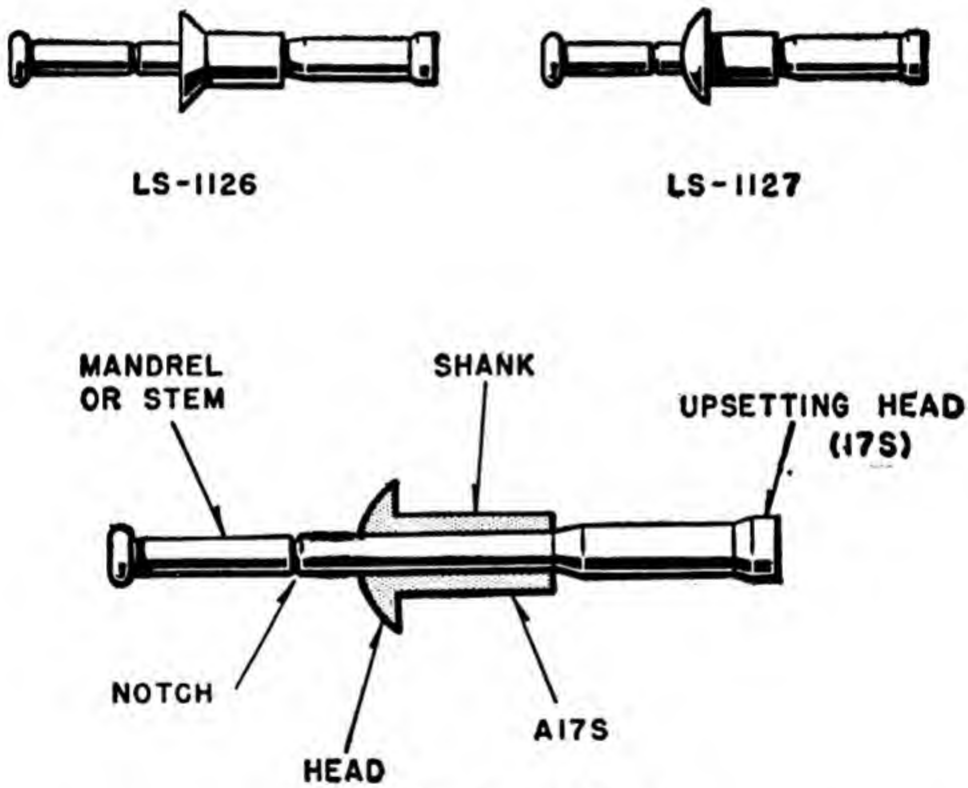


Figure 86.—Cherry rivets.

To install such a rivet, place the movable jaw of the cherry rivet gun over the rivet stem. As you apply pressure, the gun pulls the stem end of the stem which has the upsetting head INTO the rivet, at the same time holding the rivet head firmly against the sheet. By means of this process, the sheets are drawn together and a head is formed on the rivet SHANK.

There are two types of cherry rivets—the hollow type and the SELF-PLUGGING TYPE. The Navy FORBIDS the use of the hollow type, so you can forget it and concentrate on learning how to handle the self-plugging type.

The self-plugging cherry rivet is made with either

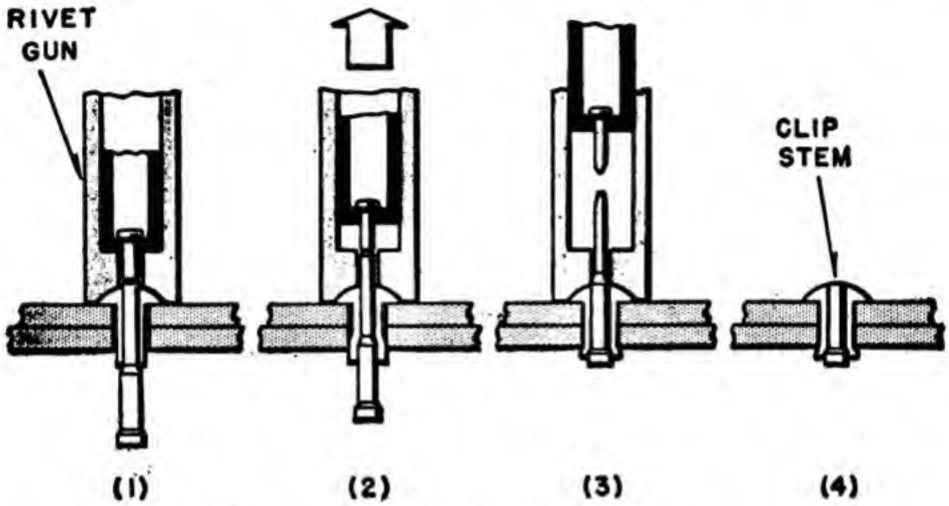


Figure 87.—Installing a self-plugging cherry rivet.

brazier head (AN456) or a countersunk head (AN426). It is of two piece construction and essentially the same as the hollow type with ONE IMPORTANT EXCEPTION. The stem of the self-plugging type is LONGER—that is, it extends from both ends of the rivet, while the hollow cherry rivet has only the upsetting head extending below the rivet shank. Figure 87 shows a self-plugging type of cherry rivet.

That portion of the stem of the self-plugging rivet which extends beyond the tail end of the shank is SLIGHTLY LARGER than the hole in the rivet. When you operate the rivet gun, this larger portion of the stem is drawn into the rivet, completely filling it with a PERMANENT plug. A tulip head is thus formed on the blind side of the rivet.

As you continue pulling on the stem with your rivet gun, the stem breaks as in the third drawing of figure 87, leaving a broken end sticking out above the

manufactured head of the rivet. To complete your riveting job, you must trim this stem down flush.

Figure 87 also shows the series numbers of self-plugging rivets. LS1126 is the countersunk head type. LS1127 is the brazier head type. LS1128 is a special type with countersunk head. It is .009 to 0.16 inch larger in shank diameter. The idea is to use it whenever you find that the rivet hole has been slightly enlarged by the dimpling process.

WHAT SIZE?

Cherry rivets are made in three sizes—$\frac{1}{8}$, $\frac{5}{32}$ and $\frac{3}{16}$ of an inch. Rivets of each of these diameters can be obtained in grip lengths for all material thicknesses from 0.30 to .0391 inch.

Self-plugging cherry rivets vary in grip length by 16ths of an inch from $\frac{1}{16}$ to $\frac{3}{16}$ inch.

These sizes are identified by the code shown on P. 174. For example, a countersunk head, self-plugging type rivet with a shank diameter of $\frac{1}{8}$ inch and a nominal grip length of $\frac{3}{16}$ inch would look like this in code, LS1126-4-6. The 4 and the 6 show the diameter and grip length, respectively in 32nds.

LS-1126-4-2

- 2 — Nominal grip length in 32nds.
- 4 — Rivet shank dia. in 32nds (nominal).
- LS-1126 — Series number denoting — type of rivet.

When you are deciding which length rivet to use, you must first figure the combined thickness of the sheets to be fastened together and then select a rivet with a nominal grip length NEAREST that thickness.

To find the grip range for a cherry rivet, measure the overall shank length and subtract $\frac{1}{16}$ inch. Re-

gardless of rivet diameter, the result will be the nominal grip length. You have considerable leeway in picking the size to use, because cherry rivets will handle material which is 1/64 inch (0.16) inch THICKER, or 3/64 inch (.047 inch) THINNER than the nominal grip length.

The material thickness table below shows you how this works out.

MATERIAL THICKNESS TABLE			
Rivet Code No.	Nominal	Minimum	Maximum
2	.063	.030	.077
4	.125	.078	.140
6	.1875	.141	.203
8	.25	.204	.265
10	.3125	.266	.328
12	.375	.329	.391

For example, if the sheets to be fastened have a combined thickness of .080 inch and are not dimpled, you should use a rivet with a 1/8 inch nominal grip—that is,

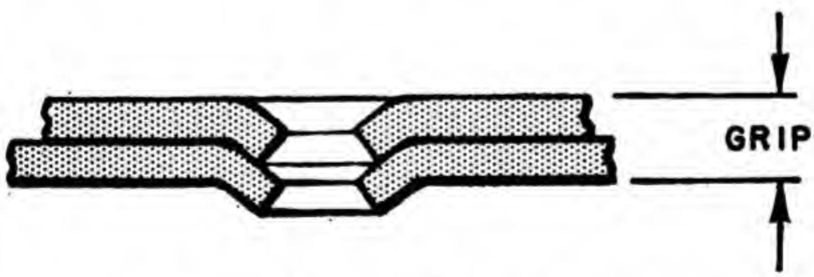


Figure 88.—Figuring grip length.

a No. 4 rivet. If the combined thickness is 0.75 inch, a rivet with a No. 2 grip length should be used.

The method for figuring the proper grip length where countersunk rivets are to be used with dimpled sheets is a little different. Take the total thickness of

the sheets PLUS the amount which the dimple extends beyond the inside surface as in figure 88.

Assume that the sheets are .052 inch in thickness and that the dimple extends .038 inch on the inside of the work. Then the TOTAL grip length would be .090 inch. Thus the required rivet would be LS1126-4-4 because the range of thicknesses covered by this rivet covers the thickness .090 inch, which you have just computed.

KNOW WHEN TO USE THEM

Navy Specification Order R-23 states the limitation on the use of cherry rivets. Here it is.

> "The rivets for blind attachment covered by this specification are intended for use in fastening primary, secondary, or non-structural parts on Naval aircraft, with the exception of CONTROL SURFACE HINGE BRACKETS, WING ATTACHMENT FITTINGS, LANDING GEAR FITTINGS, FIXED TAIL SURFACE FITTINGS, or in other similar heavily stressed locations; or in floats, hulls, or tanks."

In regard to the sizes of cherry rivets to be used the Navy says this—

> "Size approved: LS1126, LS1127, and LS1128. If you replace another rivet with a cherry rivet, the cherry rivet used shall be one size larger than the rivet it replaces. But if you are simply replacing another cherry rivet, you may replace it size for size."

You can see from the quoted specification that cherry rivets are somewhat WEAKER than AD rivets of the same nominal diameter. They are restricted in use to the conditions just described and must be of a LARGER size if they replace an ordinary rivet.

CHERRY RIVET GUNS

Figure 89 shows the two types of guns used for

cherry rivets—the hand gun shown in (*A*) and the pneumatic gun shown in (*B*).

Both guns have the same essential parts. They have an INSIDE DRAWBOLT which pulls the stem of the cherry rivet, and an outer SLEEVE over the drawbolt, which exerts a steady pressure on the rivet head. The combination of these two units forms the pulling head.

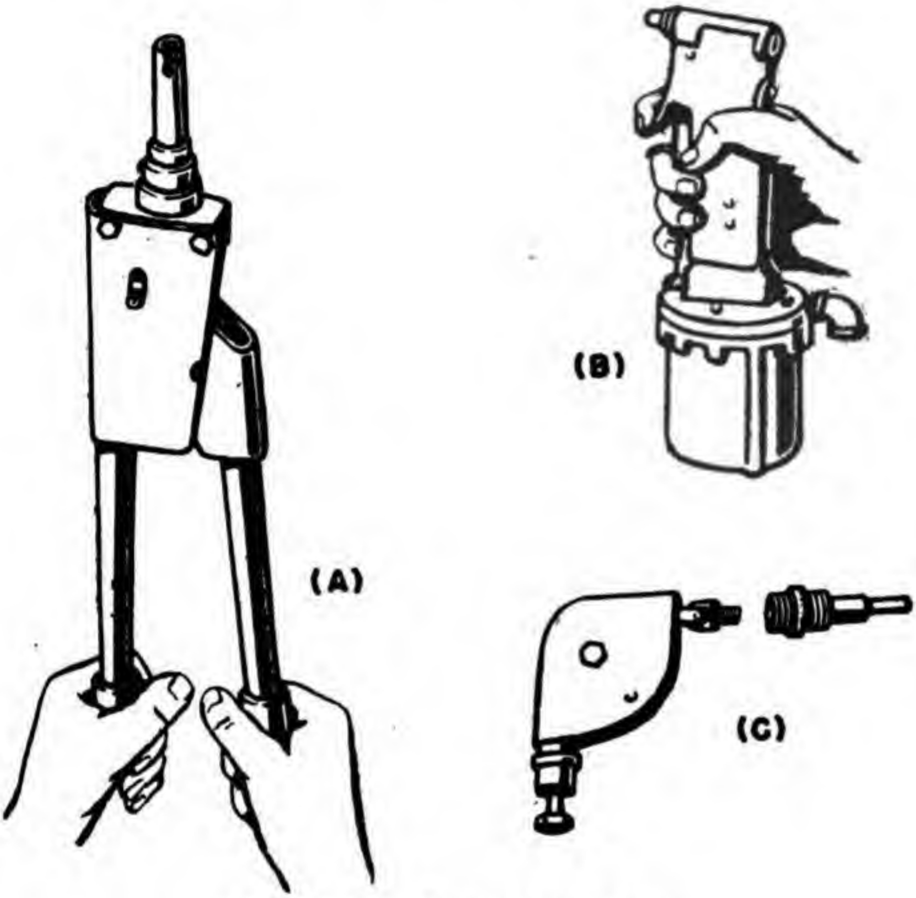


Figure 89.—Cherry rivet guns.

These pulling heads are readily interchangeable. It is necessary to have a separate size of pulling head for each diameter of rivet AS WELL AS the correct type of sleeve to handle the countersunk or brazier head. The hand gun sets can be used with the pneumatic gun, if you use an adapter.

The pulling force on the HAND GUN is exerted by means of a ratchet. It works like a car jack. Several

short strokes of the movable handle will pull in the rivet and break the stem. The PNEUMATIC guns accomplish the same result by means of compressed air.

Sometimes you may want to drive a cherry rivet in a place where the rivet could not be reached by a straight pull. Then you use an ANGLE ADAPTER which is available for both hand and pneumatic guns. Figure 89 (*C*) shows an angle adapter. It is inserted between the gun and the pulling head. The pull of the gun is transmitted through a chain drive which passes over a sprocket.

NOW DRIVE A CHERRY RIVET

But before you do, you must drill a hole for it and prepare the sheet to receive it.

In drilling holes for cherry rivets, be careful to have the hole at right angles to the sheets which are to be fastened together. The table below shows the recommended drill sizes which match the various diameters and types of self-plugging cherry rivets.

Drill Sizes			
Series	Dia.	Hole Size	Drill Size
LS-1126 and LS-1127	1/8	.128 to .132	30
	5/32	.160 to .164	20
	3/16	.192 to .196	10
LS-1128	1/8	.137 to .141	29
	5/32	.177 to .181	16
	3/16	.206 to .210	5

Here are some more Navy specifications. These refer to drilling holes for the cherry rivets.

> "Cherry rivets shall be installed in rivet holes that approximate the shank diameter of the rivet as closely as possible."

"In cases of dimpled assemblies, the rivet holes shall be drilled AFTER the sheets are dimpled at the pilot holes."

After you have finished drilling, burr the holes and clean the chips from between the sheets.

One more precaution—before you start riveting, see that the sheets are CLAMPED at reasonable intervals. If they are not clamped tightly together, neither the bucked head nor the manufactured head will seat well.

Now you have the sheets drilled and the burrs and chips removed. The next step is to pick out the proper size of cherry rivet according to the diameters and lengths given a few paragraphs back.

Then put a pulling head of the corresponding size on your gun.

AT RIGHT ANGLES

Now, either insert the rivet into the drill hole or else stick it into the pulling head of the gun. In either case, before you buck the rivet, be sure to see that the rivet stem is properly placed in the CENTER of the gun's drawbolt. Don't forget to see that the gun is at RIGHT ANGLES to the sheets being riveted.

If you are using a hand gun, hold the stationary handle in one hand and give the movable handle several strokes with the other hand. This should be enough to pull the stem into the rivet shank, breaking the stem above the rivet head.

You get the same results with the pneumatic cherry rivet gun by squeezing the trigger. It works like an ordinary pneumatic riveter.

The portion of the stem sticking up above the rivet must now be cut off flush with the manufactured head. Use a pair of flat ground nippers. As a final step the Navy says that "the plug end shall be coated with a 10 percent solution of chromic acid."

You must handle your cherry rivet gun carefully. ONLY a qualified mechanic should make repairs on it when they become necessary.

EXPLOSIVE RIVETS

An explosive rivet is just what its name implies. It is made with a cavity in the shank which contains an explosive charge. It is, like the cherry rivet, a special type of blind fastener designed especially for use on those jobs in aircraft repair work where the back of the rivet CANNOT be reached with a bucking bar. Explosive rivets look much like an ordinary aluminum alloy rivet.

The end of the hole which contains the explosive

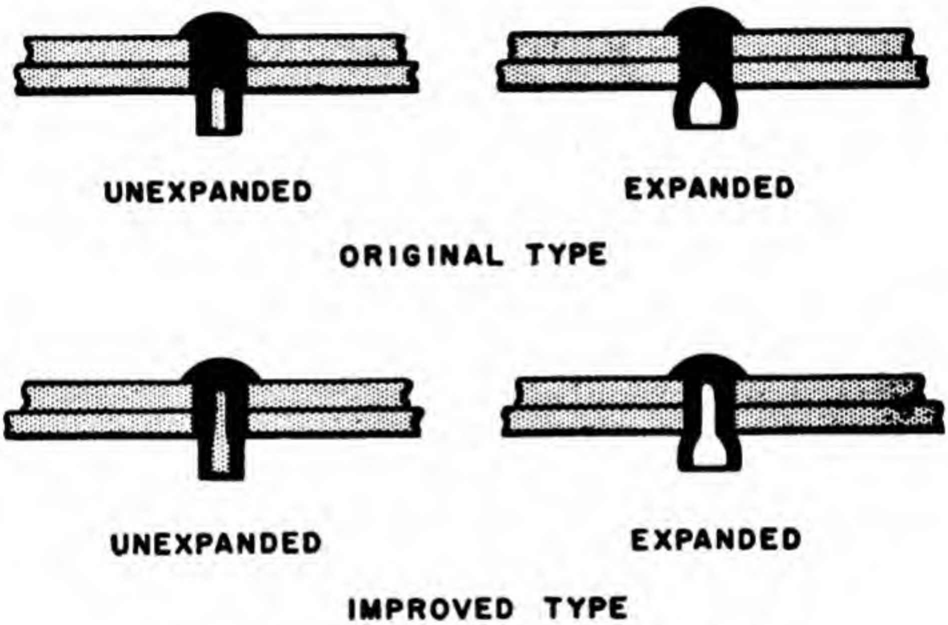


Figure 90.—New and old explosive rivets.

charge is sealed with a waterproof coating. The charge explodes and spreads the end of the rivet to form a clinched head when the tip of a heated riveting iron is applied to the manufactured head of the rivet. The clinched head is 15 to 30 percent larger than the original shank diameter.

Explosive rivets are made from 17ST aluminum alloy and are ready to use when you get them. Heat-treatment or refrigeration is not necessary. Obviously, however, the nature of explosive rivets will make you want to keep them in a cool place.

A comparatively new type of explosive rivet is now is service. This rivet carries an explosive charge that goes right up the shank to the head of the rivet. When it explodes, it expands the entire shank, so that the rivet is locked firmly in the hole. Take a look at figure 90 and you'll get the idea. It shows the comparison between the older type explosive rivet and the new model.

TYPES OF EXPLOSIVE RIVETS

At present, the improved rivets are being manufactured in two sizes—5/32 inch and 3/16 inch with modified brazier head types.

The older type is available with both modified brazier head and the 100-degree countersunk head. These two different head types are shown in figure 90.

These older type rivets come in three shank diameters, 1/8, 5/32, and 3/16 inch. The grip lengths vary from .020 inch in a rivet with 1/8 inch shank diameter to a maximum of .240 inch in rivets with shank diameters of 5/32 and 3/16 inch. Tables VI and VII show the actual grip lengths which are available.

TABLE VI

Grip length or total thickness to be riveted		Proper size BRAZIER HEAD RIVET to use			Color of Rivet
Min.	Max.	If 1/8" dia. is indicated	If 5/32" dia. is indicated	If 3/16" dia. is indicated	
0.025"	0.044"	DR-127A-4			Yellow
0.045"	0.064"	DR-127A-6	DR-173A-6		Black
0.065"	0.084"	DR-127A-8	DR-173A-8	DR-204A-8	Red
0.085"	0.104"	DR-127A-10	DR-173A-10	DR-204A-10	Blue
0.105"	0.124"	DR-127A-12	DR-173A-12	DR-204A-12	Brown
0.125"	0.144"	DR-127A-14	DR-173A-14	DR-204A-14	Yellow
0.145"	0.164"	DR-127A-16	DR-173A-16	DR-204A-16	Black
0.165"	0.184"	DR-127A-18	DR-173A-18	DR-204A-18	Red
0.185"	0.204"	DR-127A-20	DR-173A-20	DR-204A-20	Blue
0.205"	0.224"		DR-173A-22	DR-204A-22	Brown
0.225"	0.244"		DR-173A-24	DR-204A-24	Yellow

Here is the way to decipher the code number of an explosive rivet. The code is made up of a series of numbers and letters which indicate—

TABLE VII

Grip length or total thickness to be riveted		Proper size COUNTERSUNK RIVET to use			Color of Rivet
Min.	Max.	If 1/8" dia. is indicated	If 5/32" dia. is indicated	If 3/16" dia. is indicated	
0.045"	0.064"	DR-134-100-6			Black
0.065"	0.085"	DR-134-100-8	DR-173-100-8		Red
0.085"	0.104"	DR-134-100-10	DR-173-100-10	DR-204-100-10	Blue
0.105"	0.124"	DR-134-100-12	DR-173-100-12	DR-204-100-12	Brown
0.125"	0.144"	DR-134-100-14	DR-173-100-14	DR-204-100-14	Yellow
0.145"	0.164"	DR-134-100-16	DR-173-100-16	DR-204-100-16	Black
0.165"	0.184"	DR-134-100-18	DR-173-100-18	DR-204-100-18	Red
0.185"	0.204"	DR-134-100-20	DR-173-100-20	DR-204-100-20	Blue
0.205"	0.224"		DR-173-100-22	DR-204-100-22	Brown
0.225"	0.244"		DR-173-100-24	DR-204-100-24	Yellow

The type.

The actual shank diameter.

The type of head (and degree of countersink if it is of that type head.)

The grip in hundredths of an inch.

Look at figure 91. It explains the meaning of a code number. The code in this figure is written DR-127-A-6. DR indicates a DuPont rivet. The number 127 stands for the diameter in thousands of an inch (in this case, a 1/8 inch nominal diameter). The letter A means that

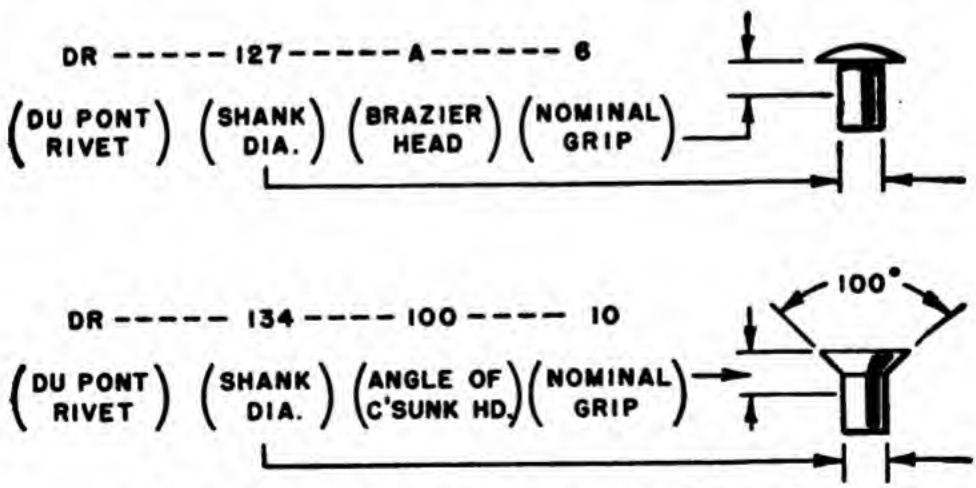


Figure 91.—Code numbers for explosive rivets.

the rivet has a brazier head. The final number, 6, indicates the grip length in hundredths of an inch (in this case from 0.45 to .064 inch). As you can see, this

figure 6 refers to the maximum thickness of metal which the rivet will take, just as in the code number for a Shakeproof fastener.

Another example of the code—this time for a countersunk head—is shown in figure 91. Here you have the number DR-134-100-10. This means that the rivet is a DuPont rivet, .134 inch in shank diameter (still considered ⅛ inch nominal diameter), with a 100° countersunk head, and with a grip length of .10 inch.

If you compare these codes with the tables given earlier of the actual diameters of the rivets, you will find that the code varies a few thousandths of an inch from the nominal diameters of ⅛, 5/32, 3/16 inch. The reason is that explosive rivets must fit very snugly because the shank must not expand.

Explosive rivets are coated with colors to indicate the range of metal thicknesses for which they can be used. The key to these colors is also given in tables VI and VII.

THERE ARE SOME LIMITATIONS

Explosive rivets are simple to use and you can install them very quickly. Certain limits, however, have been placed on their use. Because of the fact that these rivets are hollow at the formed head, they are not as strong as solid rivets of the same size. This is what the Navy has to say about their use.

> "Explosive rivets may be used for primary and secondary installations, WITH THE EXCEPTION OF—
>
> Wing attachment fittings
> Control surface hinge brackets
> Landing gear fittings
> Fixed tail surface attachment fittings
> Other similar heavily stressed locations."

These are some more limitations which the Navy imposes upon the use of explosive rivets.

"These rivets should only be used in applications where it is possible to hold the sheets of material to be fastened by CLAMPS or other suitable fasteners while the rivets are exploded.

Flush head explosive rivets should not be used in dimpled sheets.

Explosive rivets should be installed with tools supplied by the manufacturer and in accordance with the manufacturer's instructions.

The rivets should not be used in the manufacture or repair of fuel tanks or oil tanks.

Explosive rivets should be used only on all metal or non-inflammable materials, and in areas where NO EXPLOSIVE VAPORS are present.

Explosive rivets may be used for patching hulls and floats provided that a suitable synthetic rubber sealing material or compound is used.

Explosive rivets should be stored as recommended by the manufacturer.

In the replacements of rivets, the explosive rivet shall be one size larger if it replaces an ordinary rivet. It it replaces another explosive rivet it can be matched size for size. These rivets shall not be used in a given joint to replace SO MANY solid rivets that the result is an overstressing of the REMAINING solid rivets."

GUN FOR EXPLOSIVE RIVETS

The rivet gun for the explosive rivet is an electrically heated iron, somewhat similar to a soldering iron. The principle on which the gun operates involves the passing of low voltage and high current through two conducting leads and up into a metal tip. Figure 92 shows two types of explosive rivet guns.

Operation of the gun is simple. All you do is hold the rivet in place with the gun and squeeze the trigger. This closes the circuit causing the tip to heat. The heat

Figure 92.—Explosive rivet guns.

detonates the charge in the rivet and locks it firmly in the hole.

PREPARATION BEFORE RIVETING

But you don't want to get ahead of yourself here. The first thing to do is figure on the thickness of the metal to be riveted and decide what kind of rivet you need. Using table VI and VII for your guide, select the right rivet for the job. Be sure you have the correct grip length.

Drill the pilot holes, and use some type of set fastener—maybe Clecos—to hold the sheets together. Now redrill the holes using the proper size drill as given in the table below.

If you're using the original type of rivets, with a charge that just goes part way up the shank, it is EXTREMELY IMPORTANT that the exact size of drill be used. In these older rivets there is no expansion of the shank in the drill hole.

However, if you're using the new improved-type rivet,

PILOT AND FINISH DRILL SIZES

Rivet Diameter	Rivet Number	Pilot Drill	Finish Drill
1/8" Brazier	DR-127A	#31 or smaller	3.25mm. (0.1275")
1/8" (78°) Countersunk	DR-134-78	#30 or smaller	#29—(0.136")
1/8" (100°) Countersunk	DR-134-100	#30 or smaller	#29—(0.136")
1/8" (115°) Countersunk	DR-134-115	#30 or smaller	#29—(0.136")
5/32" Brazier	DR-173A	#22 or smaller	#17—(0.173")
5/32" (100°) Countersunk	DR-173-100	#22 or smaller	#17—(0.173")
3/16" Brazier	DR-204A	#12 or smaller	# 6—(0.204")
3/16" (100°) Countersunk	DR-204-100	#12 or smaller	# 6—(0.204")

the hole can be SLIGHTLY larger than the old size rivets. Why? Because with the new rivets, the shank expands after explosion, resulting in a good tight fit in the hole.

USING THE GUN

There are several types of old and new rivet guns in use now. One of the newest types is shown in figure 92 (*B*) and another type still in common service is shown in figure 92 (*A*).

Since these various guns have varying characteristics it is difficult to give you any general rules that will apply to all guns. So the main thing for you to do is find out just exactly what kind of a gun you are using and to get the word on how to use it from experienced hands.

One of the most important things is selecting the correct tip to use for the type rivet you are going to require. Be sure you get a table, or definite instructions, on what tip you need, according to the size and type of rivet to be driven.

In older type guns, it is necessary to preheat the iron for 20 to 30 minutes before using it. The new type heat up almost immediately.

Use enough pressure on the iron to insure good contact. Keep pressing until the rivet explodes. You'll be rewarded with a loud bang, and that's your signal to remove the iron and start on the next rivet. It shouldn't take more than 6 seconds or less than 1½ seconds to explode the rivet after you apply the gun. If it explodes too soon or too late, check the temperature regulation.

If a rivet won't expand, take it out and put in another one. Don't try to use it again, because rivets that fail to expand the first time will seldom expand properly if you reheat them.

NOTE THESE PRECAUTIONS

Keep rivets away from fire, and avoid temperatures

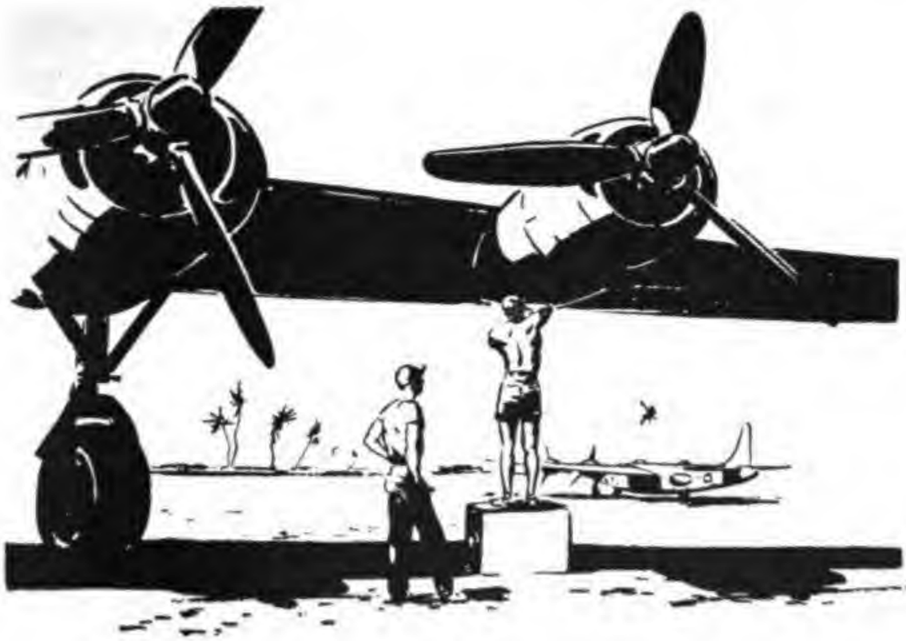
above 120°. Don't put them on steam radiators or other hot objects—for obvious reasons.

Never use explosive rivets in steel or in other metals harder than 24ST aluminum alloy.

Don't expand rivets in the presence of inflammable vapors. And never use a higher heat than is necessary to explode the rivet properly.

On the other hand, avoid using too low a heat, because the rivet will not be exploded properly nor will it have the desired strength.

DESTROY unexploded rivets.



CHAPTER 4

FASTENERS

CLECO SHEET METAL HOLDER

With the introduction of sheet metal in aircraft construction, a need arose for FASTENERS to hold the sheets tightly together and in alinement prior to fitting, drilling and riveting. Several types of fasteners have been developed, each of which possesses certain advantages or disadvantages, depending on the specific need. Some fasteners are retained as permanent parts of the structure. Others are subsequently replaced because the sheet metal is permanently fastened with rivets or by other means. In that case they are called TEMPORARY METAL FASTENERS. For best results, select the fastener which most adequately meets the requirements of your specific job.

Several types of fasteners have been developed to meet the need for temporary fastening of one sheet to another or to structural parts during the process of repair and assembly.

One of the most convenient of temporary fasteners, introduced to meet the demand for faster methods of production, is the SPRING, OR CLECO SHEET METAL HOLDER, illustrated in figure 93.

This fastener consists of a small steel cylinder with a plunger under spring tension, and is furnished in sizes

Figure 93.—Cleco fastener.

from $\frac{3}{32}''$ to $\frac{3}{16}''$. If a holder is selected of the same size as the rivet being used, the pilot and lock stem of the holder will be the correct diameter to fit the hole.

Since these holders exert a pressure of 50 pounds, and do not loosen under vibration, they can be used effectively for holding sheet metal in place when you are drilling or riveting. Gaskets prevent scratching of the metal by the holders. Special pliers or forceps are used to insert and remove them from the sheets, some working parallel to the sheet and others at an angle of 90°.

Figure 93 shows also the right way to insert it. Be careful to grip the Cleco in the pliers so that it doesn't slip and fly out.

MACHINE SCREWS were among the first devices used to provide temporary fastening of aircraft sheet metal parts.

Machine screws make secure fasteners, but on temporary jobs a lot of time is required to install and remove them, and care must be taken to avoid stretching the fastened material when tightening or loosening the

screws with tools. Such screws are made with the variously shaped heads shown in figure 94. The BUTTON head shown in figure 94 is a truss head—sometimes also called a brazier head. The FILISTER head may be had with a hole drilled through the head at right angles to the slot for the purpose of safety wiring.

Although these screws are made of several materials, those most generally used in aircraft work are made of cadmium plated steel or anodized aluminum alloy.

The sizes of machine screws are determined by the OUTSIDE DIAMETER of the threads, by the number of threads per inch, and by the length.

The diameters range from 1 to 10 gage, plus ¼ inch, $\frac{5}{16}$ inch and ⅜ inch fractional diameters. Screws are made with National Fine (N.F.) and National Coarse

Figure 94.—Machine screws.

(N.C.) threads. The number of threads per inch varies for different screws. The most common for aircraft use has 32 threads per inch.

Thus when a machine screw is referred to as 8-32, 10-32, and so on, it simply means a screw with a No. 8 or No. 10 diameter, having 32 threads per inch. The standard sizes used are 4-40, 6-32, 8-32, and 10-32.

Machine screws come in various lengths designated in 16ths. Aluminum alloy screws of the fine thread series that are smaller than 10-32 should NOT be used because the threads are easily stripped.

A-N SPECIFICATIONS FOR MACHINE SCREWS

Here is what a code number for a machine screw means.

AN500C-6-7 — Length in 16ths of an inch (in this case 7/16 inch)
- Diameter No. 6
- Corrosive resistant steel (Cadmium plated steel)
- Part Number Coarse thread
- Army and Navy

AN510D-8-5 — Length, 5/16 inch
- Diameter No. 8
- Aluminum alloy
- Part Number Fine thread
- Army and Navy

WHERE DO YOU USE MACHINE SCREWS?

Machine screws should not be used in PRIMARY airplane structures, or for the attachment of superstructure

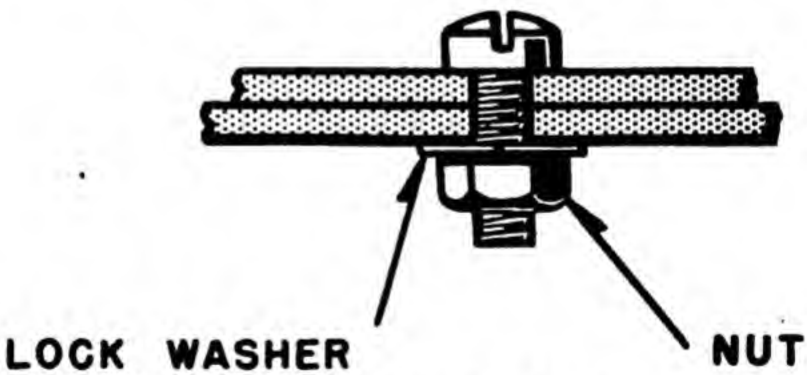


Figure 95.—Safety lock nut.

or accessories WHERE THEIR FAILURE WOULD RESULT IN DANGER TO PERSONNEL. If you don't have Cleco sheet fasteners or other suitable temporary fasteners, you may use machine screws to hold sheets together during assembly. These screws are also used with various types of SAFETY LOCK NUTS. Figure 95 shows a

machine screw with one of these nuts. Machine screws are usually used with such nuts in assembling inspection plates, temporary patches, and also in connecting the skin to certain parts of the airplane structure.

Your screws should be long enough to extend through the assembled parts until two threads show on the opposite side. Thus you make use of the COMPLETE bearing strength of the screw and nut.

Screws MUST NOT BE CUT OFF either before or after they are installed because this would result in damaging the threads. Use thin aluminum alloy washers under the heads of steel screws to keep them from marring and scratching the skin.

PARKER KALON SCREWS

These screws are made of very hard steel. For use in aircraft, the steel is plated to prevent corrosion. Sometimes the screws are made of stainless steel for the same reason. They are designed to cut their own threads in softer aluminum alloy, and thus a nut is not necessary.

There are two types of Parker Kalon screws—Type A, designed for joining sheet not heavier than .050 inch, and Type Z, for joining light and heavy sheet from 0.15 inch to .203 inch in thickness.

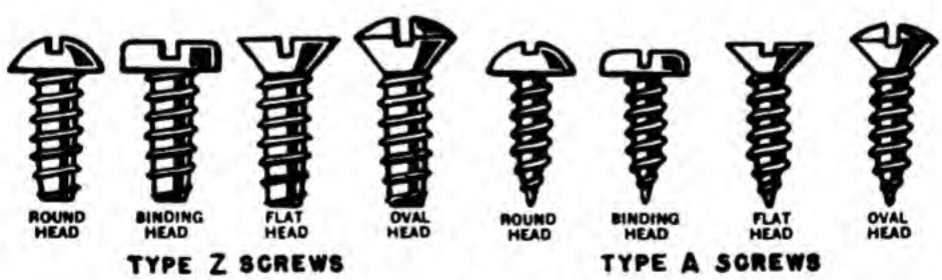


Figure 96.—Parker Kalon screws.

The more common head styles are shown in figure 96. They may also be obtained with recessed Phillips' heads. In general, you will find that the blunt Z type is most satisfactory because of its great range of use. The pointed A type, however, is best to use if the alinement

of the holes is difficult. They come in varying lengths to meet the needs of particular sheet thicknesses.

You decide upon the hole size for the insertion of one of these screws by taking into account the NATURE, HARDNESS, AND THICKNESS of the metal which you are to fasten.

For instance, thicker and harder materials require SLIGHTLY LARGER holes, because a greater driving effort is needed. The idea, however, is to use the SMALLEST practical size of hole. Look at the table below. You may use it as a guide in selecting the drill size for the more common sizes of Parker Kalon screws when they are to be used with aluminum alloy sheets or tubes.

HOLE SIZES FOR PARKER KALON SCREWS

No.	Dia.	Metal Thickness	Dia. of Hole	Size of Drill
4	.112	.015 to .064	.076 to .089	48 to 43
6	.137	.015 to .064	.101 to .106	38 to 36
8	.163	.025 to .128	.116 to .149	32 to 25
10	.186	.031 to .162	.140 to .162	28 to 21

USING PK'S

Parker Kalon screws (called PK's) are often used to hold sheets of metal together temporarily during construction. They are also used for emergency repairs on skin surfaces. You can use this type of screw for permanent fastening of instrument panels and cabin linings and with various plastic materials.

Self tapping screws used in aluminum alloy should be installed with a phenolic or aluminum washer between the head of the screw and the alloy so that the screw will not burr the sheet. Coat both the washer and screw with a zinc chromate base before inserting the screw. This coating makes a complete seal and prevents the entrance of moisture.

WARNING—Never use self-tapping screws under these conditions:

As fastenings to primary structures.

Where they would be subject to excessive shear stress.

As fastenings for superstructure accessories if failure would result in danger to personnel.

Where loss of the screw would permit a joint to be opened to air flow.

Where such screws would be subject to frequent removal and replacement.

If it is necessary to replace self-tapping screws, do one of two things. Either re-drill the hole and use a screw at least one size larger; or, if you must replace a screw with one of the SAME size, install it with a lock washer between the screw head and the metal.

ANCHOR NUTS

The anchor nut or plate nut, as it is sometimes called, is self-locking and is characterized by FLANGES extending from opposite sides of the nut. These flanges are riveted to the sheet metal to provide a means of fastening the nut to the top sheet of the structure. The types most often used are shown in figure 97. The self-locking device of the plate nut consists of a rubber or fiber collar which is held securely in the top of the nut.

The plate nuts used in aircraft are made of aluminum alloy with an anodic finish, or of cadmium plated steel. They come in various sizes. The most common sizes of plate nuts are Nos. 6-40, 6-32, 8-36, 8-32 and 10-32. These figures indicate the size and number of threads per inch in the nut. The rivet holes in the lug (flange) are usually .098 inch (No. 40 drill).

Suppose, as frequently will happen, you must make a repair upon a CLOSED SURFACE in an airplane structure. In this case you would have to make an opening so that the work could be done from the inside. Upon completing the repair, you would cover the hole and use

anchor nuts (plate nuts) and screws to hold the cover in place.

The use of plate nuts is usually limited to structures which are frequently removed and thus must be quickly detached. Using a plate nut as a fastener enables you to have a solid joint in spite of these conditions. For example, most metal inspection covers are held in place in this manner.

When you install an anchor nut you must be extremely careful in riveting the lug. The point is to make

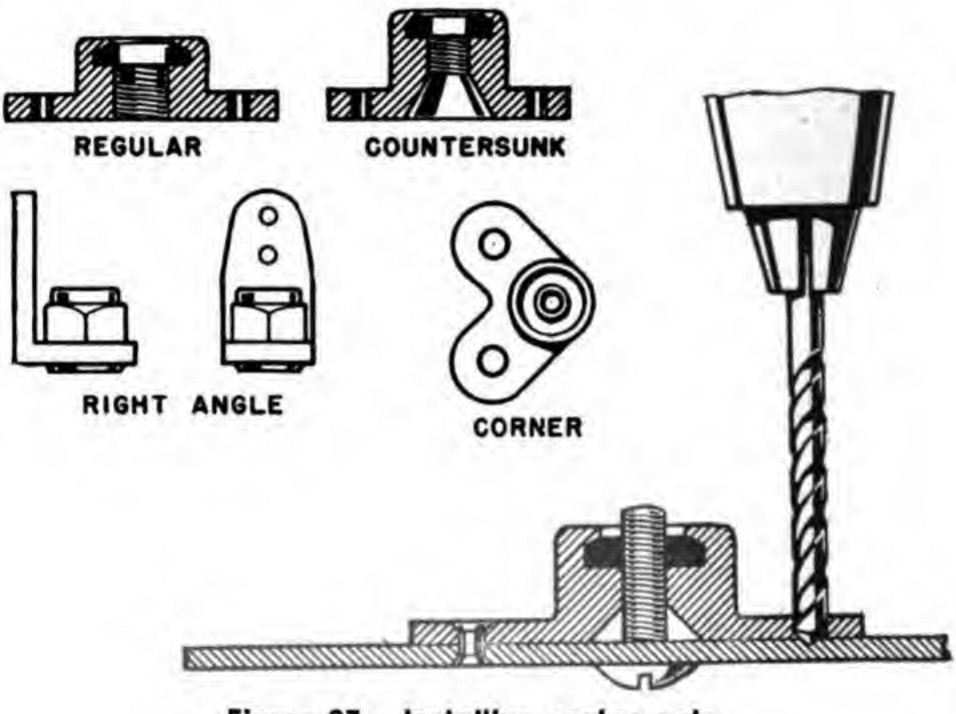


Figure 97.—Installing anchor nuts.

sure that the hole through the nut LINES UP with the bolt hole. Otherwise it will be impossible to screw the bolt into the nut because the bolt will refuse to engage the threads of the nut. And even if the threads DO catch, they will usually be cross-threaded and either the nut or bolt will be ruined.

To avoid such an unhapppy situation, insert the bolt through the hole in the sheets which are to be fastened and then screw the anchor nut down tightly to the sheet, as in figure 97. Next line up the lugs in their riveting

position and drill holes through them. Now take out the screw and RIVET THE ANCHOR NUT INTO PLACE. All anchor nuts which have lugs to hold them in place are usually countersunk riveted so that the bearing surface will be smooth.

CHANNEL GANG NUTS

The parts of an airplane structure that have to be frequently removed in field service, such as the floor plates of flying boats, are installed with channel gang nuts. The fastener has other names, one of the most common of which is "strip plate."

Channel gang nuts are simply U-type channels constructed so that the anchor nuts are inserted and held into position by the top ledge of the channel as in figure 98.

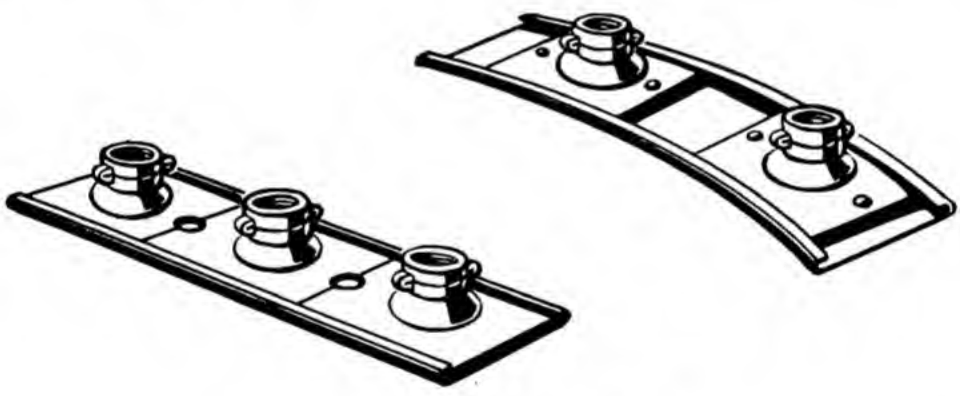


Figure 98.—Channel gang nuts.

If the nuts are placed end to end, each end of the channel is closed so that the nuts cannot slip out. The use of these channels saves time because you don't have to rivet EACH anchor nut into place. The channel, however, must be held in position by an adequate number of rivets.

Often, if the structure is removed repeatedly, one of the nuts in or near the center of the channel will become stripped and you will have to replace it. If you cannot SPREAD the channel enough to allow you to remove the

bad nut, you will have to start at one end and remove all of the nuts until the bad nut is reached. Then you must replace it with a new one. This method is used if the nuts are end to end.

The nuts are held in the channel in various ways. Figure 98 shows two types of gang channels. One shows the anchor nuts jammed end to end. The other shows how they may be secured by a dimpling process.

AVOID USING ANCHOR NUTS under the following con-conditions.

Where they are subjected to high temperature—unless, of course, they are especially made to withstand heat.

Where less than three nuts are used to fasten a main structural member.

At joints which will subject the bolt or nut to rotation. Such rotation would tend to loosen them.

Don't use only one rivet anchor. You need more.

DZUS FASTENERS

Dzus fasteners are made of nickel steel which has been heat-treated and cadmium plated. They consist of a grommet, spring and stud. The grommets are made

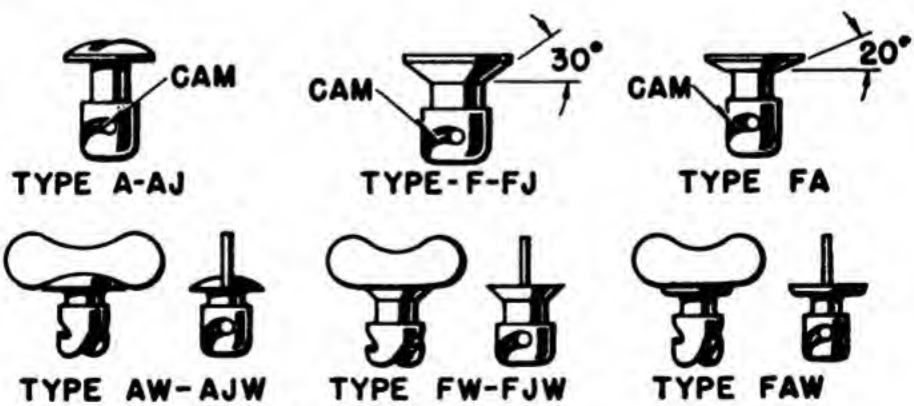


Figure 99.—Dzus fasteners.

of aluminum. These devices are used to fasten inspection covers, cowls, fairing, flooring, paneling and the like.

Dzus fasteners are installed easily. They can be opened quickly, yet they hold securely when they are locked. Some more advantages—they have no loose parts to be lost, they are adaptable to many installations, and they look neat.

They come with different shaped heads and dimensions to fit various requirements. Figure 99 shows several types.

Type A has an oval head. Type F has a flush head, and so also does Type FA, although in this case the head has a ROUNDED EDGE. If the letter J is added to the symbol—as in AJ and FJ—it indicates that the fastener has a LONGER UNDERCUT below the head than the Types A and F. Type HF has a hexagonal head.

If the letter O follows in the symbol—for instance AO—it means that the fastener has NO UNDERCUT AT ALL, in order that it may be removed when unlocked. This type is not used very commonly.

The letter W in a symbol means that a WING is attached to the head.

When you see these symbols, you will also notice that there are figures following the type letters. For instance A3-20. The FIRST figure after the type letters indicates the body diameter of the fastener in sixteenths of an inch. The number following the dash (—) gives the length (L) of the fastener in hundredths of an inch.

Here are some samples.

Type A3-20 oval head has 3/16 inch body diameter and .200 inch length.

Type FJ4-25 flush head, long undercut, has a 1/4 inch body diameter and .250 inch length.

Type FAW5-35 flush head (with rounded edge) wing attached to head has a 5/16 inch body diameter and .350 inch length.

Type AO6½-50 oval head without undercut, has a 13/32 inch body diameter and .500 inch length.

All standard springs are indicated by the letter S. The figure following this letter indicates the size of

fastener with which the spring is used. The number after the dash (—) shows the height of the spring.

For example, take Type S3-200. This symbol means that the spring is a standard one for use with a number three fastener and that it is .200 inch high. Different spring heights are available for each fastener.

Then there are SPECIAL SPRINGS which are useful for installation in box corners and panels which would be subject to either horizontal or vertical movement, as in figure 100.

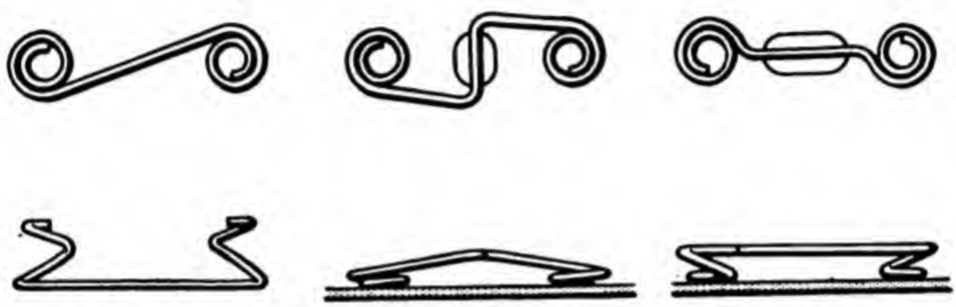


Figure 100.—Special springs.

The designations of standard grommets are similar to those for springs except that they are preceded by the letters GA and GF. For instance, a symbol such as GA6½-375, indicates a grommet to be used with a Type A or AJ, 6½ fastener with an overall length of .375 inch.

Tools available for the different sizes and types of fasteners are shown in figure 101.

Figure 102 gives you installation instructions and a key to the proper tools, drill sizes and so on.

Type F3 and FJ3 Dzus fasteners are installed WITHOUT grommets. Types F and FJ, A and AJ can be installed either with or without grommets.

The springs, grommets, and fasteners are available for use in various panel thicknesses. The thickness of the material to be fastened together determines what type of spring you must use. If the fastener is too long,

you can add thin aluminum washers under the spring seats to adjust the difference.

You must take into account a number of factors in deciding upon the correct size of Dzus fasteners for a

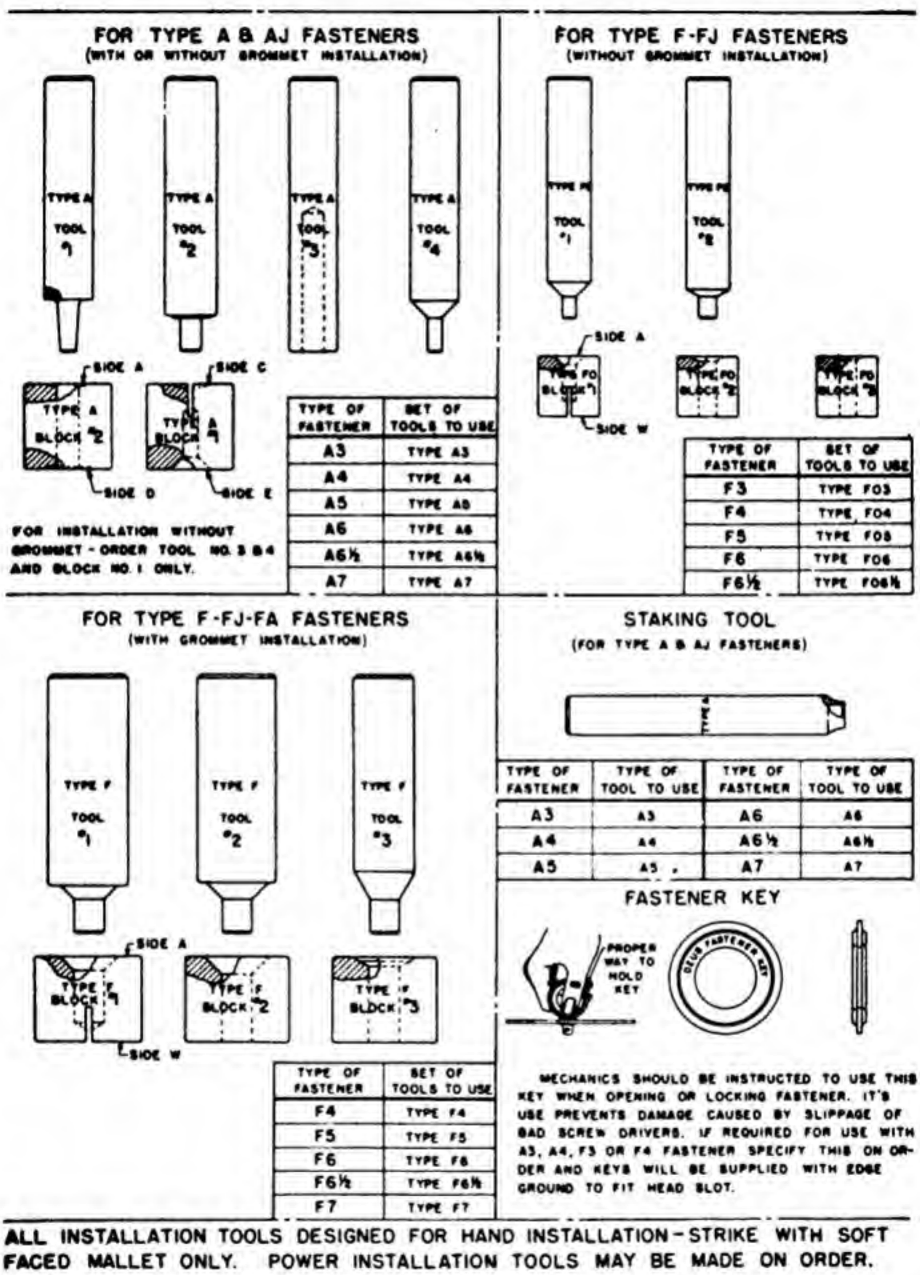


Figure 101.—Tools for installing Dzus fasteners.

certain job. One factor is the stress that will be put upon the installation and the strength necessary to keep the installation together. In repair work you decide upon a size which matches that in the original

installation or in an installation similar in type and location.

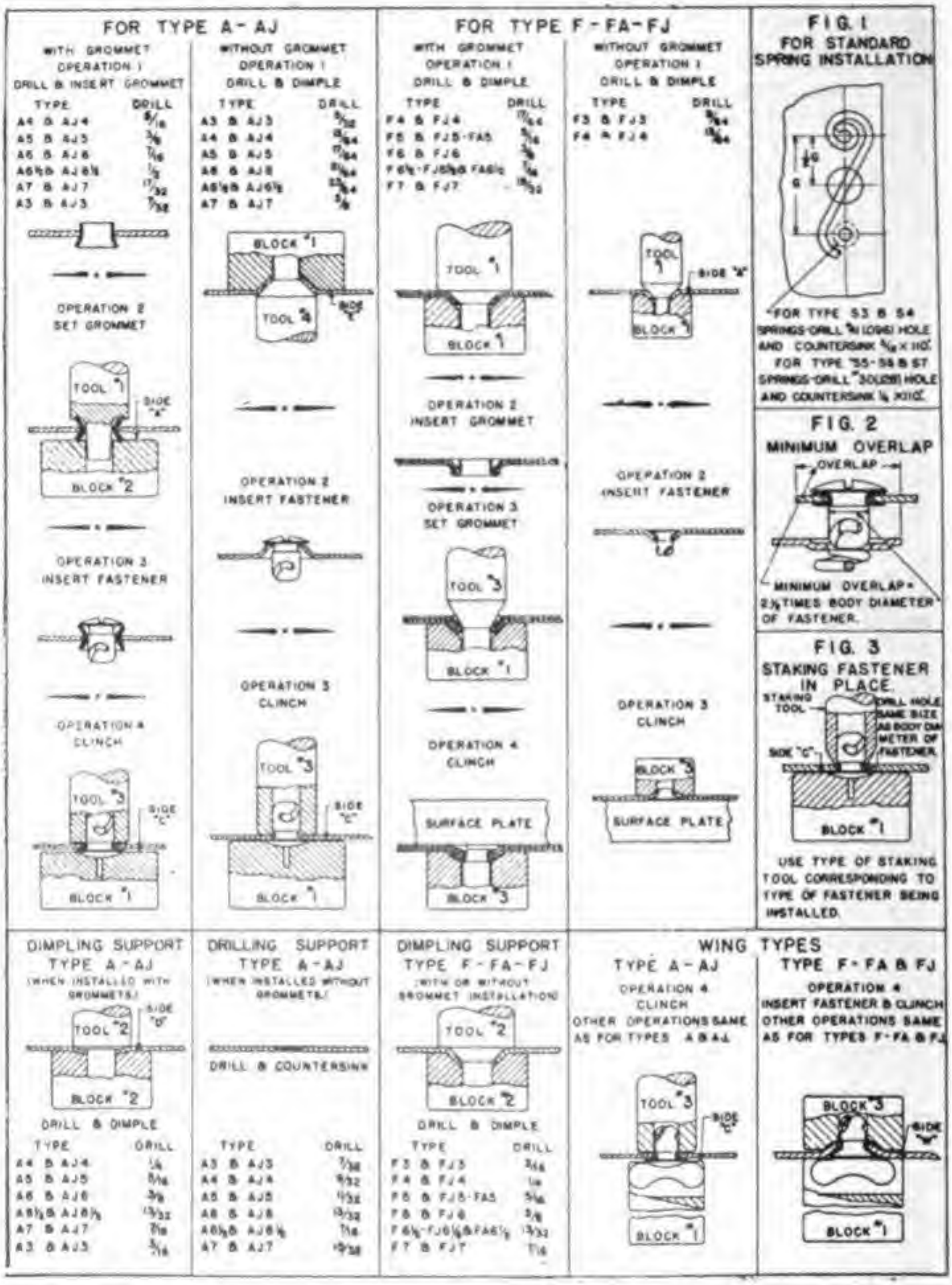


Figure 102.—Installation instructions.

RIVNUTS

A rivnut is simply a rivet type nut. It is threaded INTERNALLY and can be headed without the aid of a

bucking bar. Rivnuts are accurately machined from alloy 53S-W which is one of the most corrosion resistant aluminum alloys. They are of one piece construction, anodized, and are all ready for use when you get them.

Rivnuts are classified according to their head styles

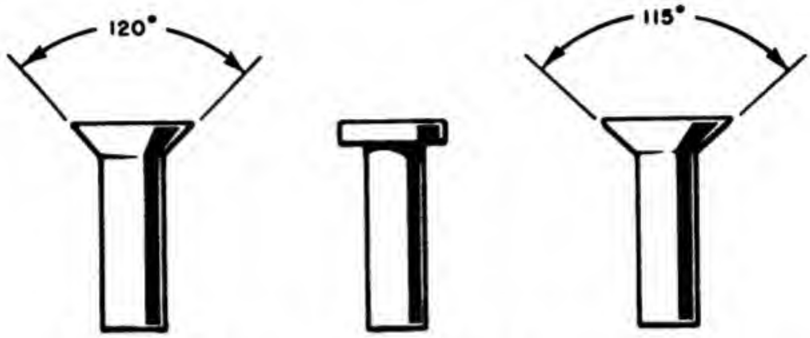


Figure 103.—Rivnut heads.

—countersunk, or flat. The countersunk head is made in two general shapes shown in figure 103.

Both countersunk and flat head styles are made in three sizes—No. 6-32, 8-32 and 10-32. These numbers

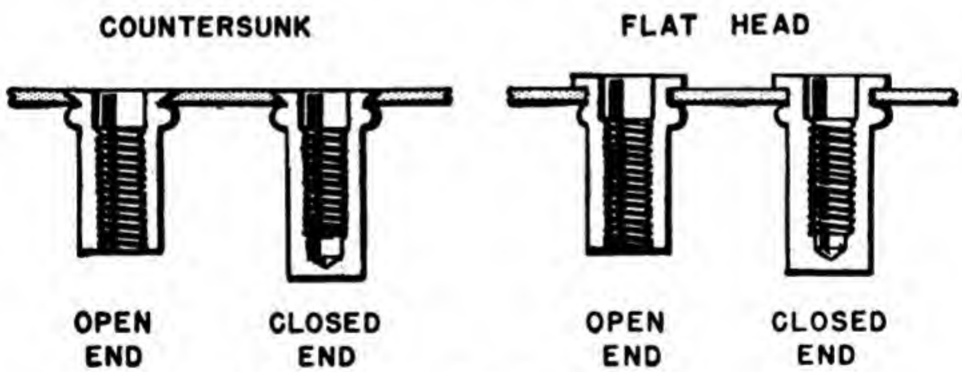


Figure 104.—Rivnuts with closed and opened ends.

indicate the diameter and number of threads per inch of the machine screw that fits into the rivnut. They have either closed or open ends, as in figure 104 and come either with or without keys. A key is not available for the thin head, countersunk type.

The GRIP RANGE of a rivnut is marked on the head

of the nut by code figures. The grip range extends from the maximum to the minimum total thickness of a sheet through which a rivnut may successfully be headed. To state it another way, the grip is the thickness of the metal which the rivet will fasten together. Table VIII shows specific grip ranges for the various sizes of flat head rivnuts.

TABLE VIII

6-45	6-75	6-100	6-120	6-140	6-160
8-45	8-75	8-100	8-120	8-140	8-160
10-45	10-75	10-100	10-120	10-140	10-160
6B45	6B75	6B100	6B120	6B140	6B160
8B45	8B75	8B100	8B120	8B140	8B160
10B45	10B75	10B100	10B120	10B140	10B160
6K45	6K75	6K100	6K120	6K140	6K160
8K45	8K75	8K100	8K120	8K140	8K160
10K45	10K75	10K100	10K120	10K140	10K160
6KB45	6KB75	6KB100	6KB120	6KB140	6KB160
8KB45	8KB75	8KB100	8KB120	8KB140	8KB160
10KB45	10KB75	10KB100	10KB120	10KB140	10KB160

The rivnut type numbers shown in Table VIII are not as hard to read as you might imagine. The figure at the left tells you the size of machine screw thread. The one at the right indicates the maximum grip in thousandths of an inch. The minimum grip equals the maximum grip of the preceding size. For the first rivnut in a series, the minimum grip equals its head thickness for countersunk types and equals .010 inch for flat head types.

You will notice that there is either a dash or one or two letters BETWEEN the figures. A dash (—) means an open end, keyless rivnut. The letter B means a closed end, keyless rivnut. K means an open end rivnut with key, and KB means a closed end rivnut with key.

Figure 105 shows you the approximate results to be expected when the same rivnut is used within its minimum and maximum grip, but with VARYING pressures on the header tool.

WHAT ARE THEY GOOD FOR?

Rivnuts are used mostly as fastening devices where it would be hard to use ordinary rivets. Rivnuts were designed at first to be used principally as nut plates for the attachment of de-icer boots. Now, however, you will use them to fasten many other accessories to the airplane structure.

YOU CANNOT USE THEM AS RIVETS IN PRIMARY STRUCTURES WHERE THERE ARE GREAT SHEAR LOADS.

You'll discover that you will use the OPEN END rivnut quite a lot in aircraft repair work. The closed end

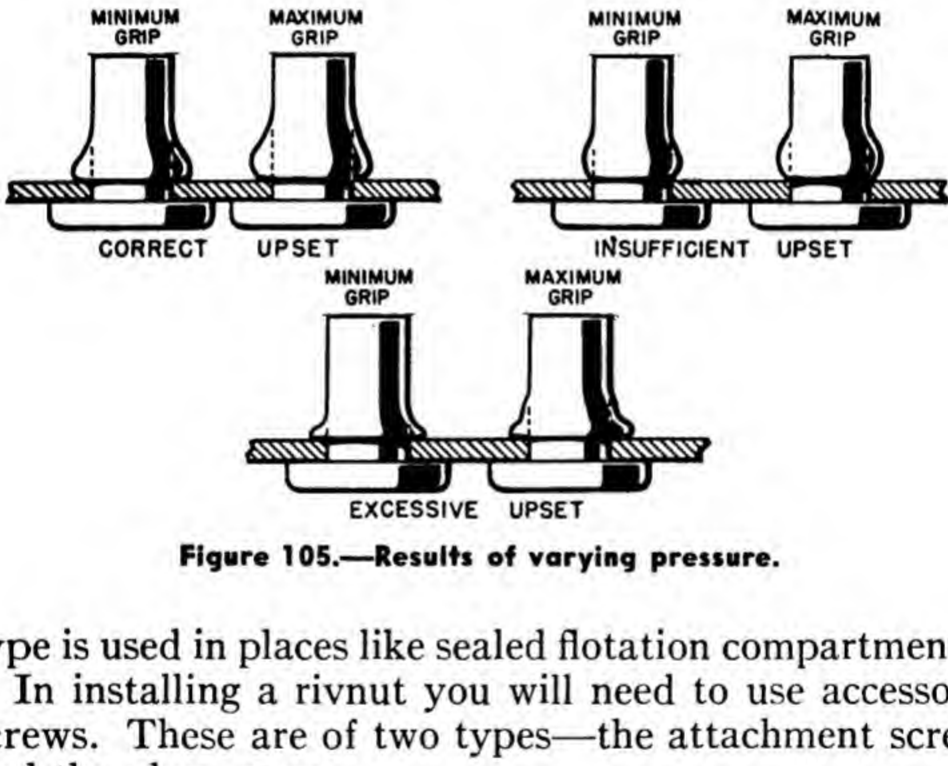


Figure 105.—Results of varying pressure.

type is used in places like sealed flotation compartments.

In installing a rivnut you will need to use accessory screws. These are of two types—the attachment screw and the plug screw.

Attachment screws are used to fasten parts that are to be joined by means of rivnuts. With this screw you must use a rivnut of the keyed type so that the screw won't have a tendency to TURN the installed rivnut.

A plug screw is the one you use when the rivnut is employed primarily to take the place of rivets. It assures added safety since open rivnuts will not bear up under any great shear load. Plug screws are also in-

stalled in rivnuts to keep salt water spray from getting into the interior of the airplane and also to keep air out of sealed compartments.

INSTALLING A RIVNUT

A special key seating tool like that in figure 106 is what you use to notch the keyway in the sheet. If you don't have such a tool handy you can form the keyway with a small round file. There are both pneumatic and hand operated tools for installing rivnuts.

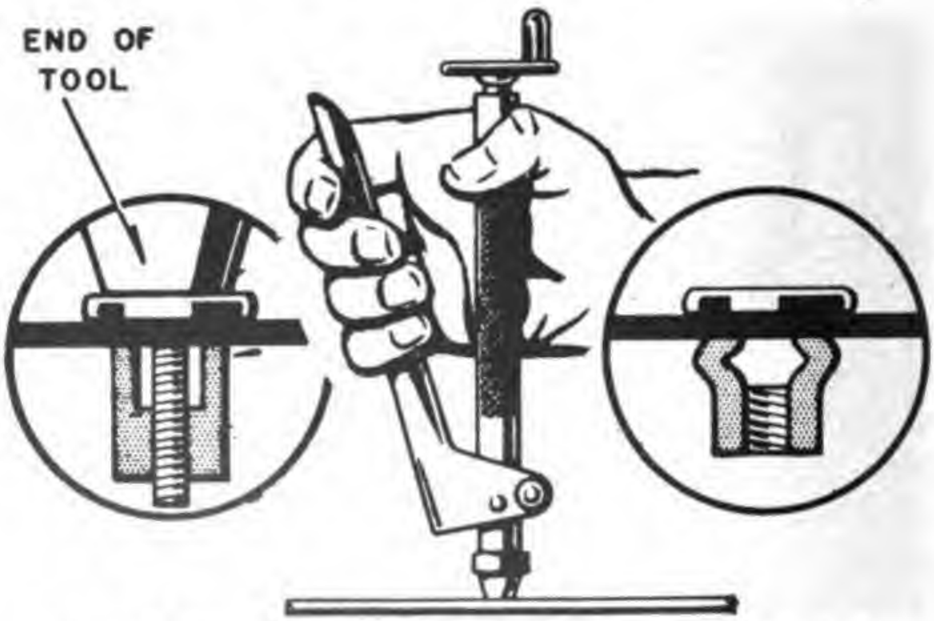


Figure 106.—Hand operated tool for rivnut installation.

Hand tools like that in figure 106 are available for straight heading and also for heading done at angles of 45° and 90° to the head of the rivnut.

You will be smart to make sample installations in order to determine accurately the thickness of the material. This is particularly true for dimpled, countersunk work, or when there is more than one thickness of material.

You must be fully as careful in drilling the hole for a rivnut as you are in drilling for regular rivets. The shank of the rivnut MUST fit snugly into the hole. In

order to obtain a smooth, round hole, it is a good idea to make a LEAD HOLE before drilling to finished size.

Look at Table IX below to get an idea of the relation in size between the lead hole and finished hole.

TABLE IX

RELATION BETWEEN SIZE OF RIVNUT, LEAD DRILL AND BODY DRILL

Size Rivnut	Lead Drill	Body Drill
No. 6-32	No. 19 (.166″)	No. 12 (.189″)
No. 8-32	No. 8 (.199″)	No. 2 (.221″)
No. 10-32	No. 1 (.228″)	¼″ (.250″)

As you learned earlier, a rivnut can be headed without the aid of a bucking bar. This is known as HEADING BLIND. How is that done? Like this.

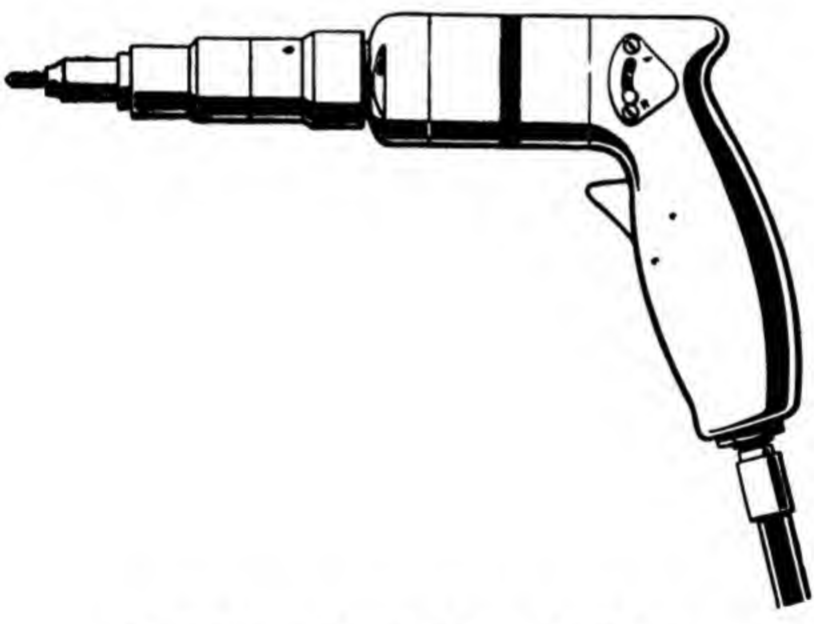


Figure 107.—Power driven rivnut tool.

If you use the hand tool shown back in figure 106 you must thread the rivnut on the mandrel with your fingers until its head rests against the anvil of the heading tool. It is important that the mandrel (screw) be

at a 90° angle to the surface of the metal at all times. Unless you see that both of these conditions are observed, your rivnut tool may easily be bent or broken.

After threading the rivnut on the mandrel, position your work and slowly squeeze the handles together until you feel solid resistance. Excessive pressure beyond this point is NOT necessary. You saw the results of various pressures in figure 105.

If the rivnuts are reinforced with S.A.E. 2330 machine screws, the joint will have three to four times more shear strength. It is a good idea to fill the rivnut with a plug screw, even if no part is attached, because you thus increase its strength and prevent wind whistle. and, as was pointed out before, a plug screw also prevents the entrance of moisture.

USE THE RIGHT SIZE

Here are some tables you can refer to which show you the grip range of various flat-head and countersunk head rivnuts. The tables will show you how to identify grip range of these rivnuts by means of the identifying marks on their heads.

Flat-head rivnut lengths in 10-32, 8-32, and 6-32 sizes are chosen according to the following thickness range of the metal in use and the corresponding marks on the head of the rivnut.

Thickness Range, in.	Identifying Mark
.010-.045	Blank
.046-.075	1 Mark
.076-.100	2 Marks
.101-.120	3 Marks
.121-.140	4 Marks
.141-.160	5 Marks
.161-.180	6 Marks
.181-.200	7 Marks
.201-.220	8 Marks
.221-.240	9 Marks

Countersunk rivnut lengths of the 100° variety, in 10-32, 8-32, and 6-32 sizes are selected in the same manner. Below is a table of their grip range.

Grip	
Thickness Range, in.	Identifying Mark
.050-.089	Blank
.090-.124	1 Mark
.125-.154	2 Marks
.155-.179	3 Marks
.180-.199	4 Marks
.200-.219	5 Marks

Countersunk rivnut lengths of the 115° variety come in the following grip ranges.

10-32 Rivnut Grip (115°)	
Thickness Range, in.	Identifying Mark
.105-.139	Blank
.140-.169	1 Mark
.170-.194	2 Marks
.195-.214	3 Marks
.215-.234	4 Marks
.235-.254	5 Marks

8-32 Rivnut Grip (115°)	
Thickness Range, in.	Identifying Mark
.075-.104	Blank
.105-.139	1 Mark
.140-.169	2 Marks
.170-.194	3 Marks
.195-.214	4 Marks
.215-.234	5 Marks

6-32 RIVNUT GRIP (115°)	
Thickness Range, in.	Identifying Mark
.065-.104	Blank
.105-.139	1 Mark
.140-.169	2 Marks
.170-.194	3 Marks
.195-.214	4 Marks
.215-.234	5 Marks

DILL LOK-SKRU AND LOK RIVET

Another type of aircraft fastener for blind spots is the lok-rivet and lok-skru (these are sometimes called Dillnuts). The lok-rivet is not tapped for a screw, but the lok-skru is. They are used for the same purposes as rivnuts. The difference is that the rivnut is a one piece device while the lok-rivet and the lok-skru come in two pieces—one screwed into the other as in figure 108.

Since both lok-skrus and lok-rivets are installed in

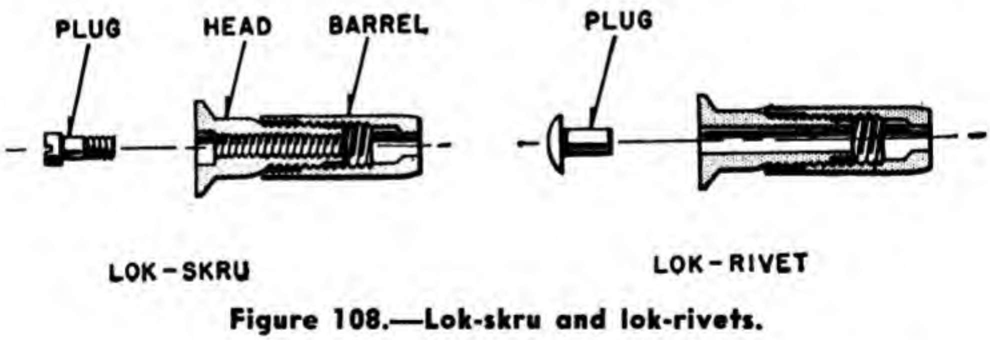


Figure 108.—Lok-skru and lok-rivets.

the same manner, the following description of the lok-rivet applies also to the lok-skru. The construction of the fastener and the method of installation is such that, when you use these fasteners as nut plates you don't need to monkey around with the key and slot which is required for the rivnut. Figure 109 shows the special tool you will use to install a lok-rivet.

Look at lok-rivet charts to decide upon the proper type, size, and length to use for the various thicknesses of metal.

HOW TO INSTALL THEM

First, you must make sure that there is adequate clearance for the lok-rivet on the UNDERSIDE of the

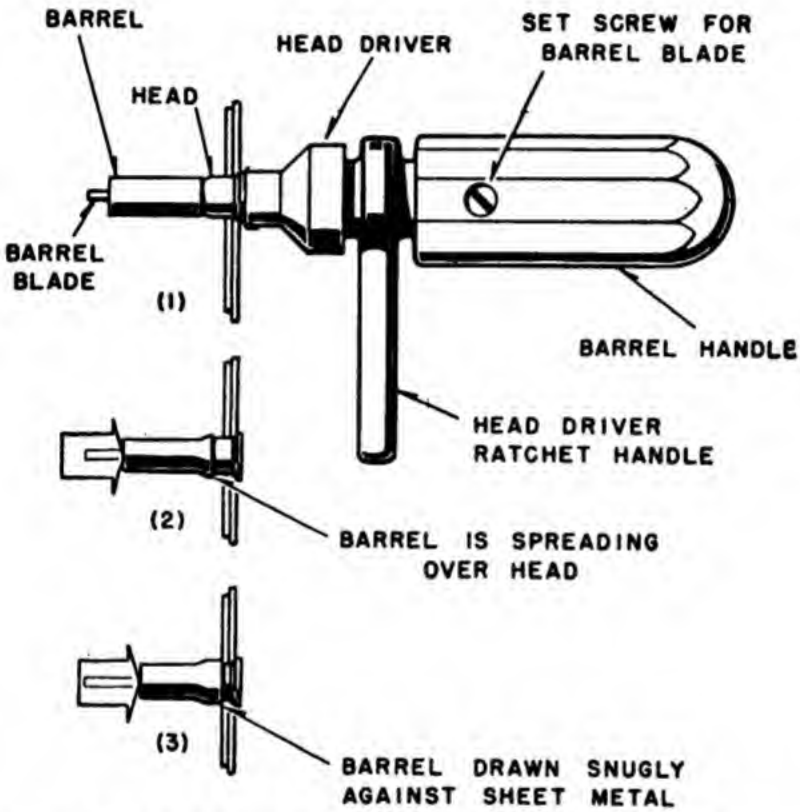


Figure 109.—Tool and steps for installing a lok-rivet.

sheet, because the lok-rivet is longer than the rivnut. Check the total thickness range of your metal and look on the chart for the proper type, size, and length of lok-rivet.

Drill the hole for this fastener to a snug, push-tight fit. It is a good idea to pre-drill and ream the hole.

Insert the tool blade into the lok-rivet so that the blade extends through the barrel slot of the lok-rivet. Set the driver firmly in the lok-rivet's head slot. Now

insert the lok-rivet into the drilled hole as in step 1 of figure 109.

Now press the tool down firmly in the lok-rivet so that the tool blade and driver are held in the slots of the lok-rivet. If you do this right, the lok-rivet head is held TIGHTLY against the surface of the sheets.

Hold the ratchet handle of your tool stationary while you turn the barrel blade handle of the tool to the left, until the sleeve or barrel of the lok-rivet has come up firmly, (as in step 2) against the metal sheet on the opposite side.

Do the final tightening by taking a quarter turn or less on the ratchet handle of your tool while you hold the tool's blade handle stationary. The head of your lok-rivet should then be drawn tightly into the sheet as in step 3 of figure 109.

Finally test the lok-rivet for tightness with a small screw-driver. You can now add any screws, plugs, attachments and reinforcements which may be necessary.

SHAKEPROOF COWL FASTENERS

The Shakeproof cowl fastener, which consists of a main spring, stud, and cross pin, is becoming more and more popular. You can see what one looks like in figure 110.

You will need two special tools when you install this fastener. One is a pliers used in assembling the cross pin in the predrilled stud. The other is a set of dimpling dies for countersinking the two sheets where you use flush heads.

Shakeproof fasteners are supplied in the five head types shown in figure 110.

These fasteners come in two standard classifications —the No. 5 which is made to withstand tension up to 500 pounds, and the No. 7, which withstands tension up to 700 pounds.

This is the way to read a Shakeproof fastener symbol. Suppose you had a symbol like this—SP-FS-5-6.

The SP stands for Shakeproof fastener.

The FS means that the fastener has a FLUSH SLOTTED head.

Other letter combinations which you might find in this position in the symbol are these.

FR—Flush recessed head
OS—Oval slotted head
OR—Oval recessed head
OW—Oval wing head

The 5 means the Army-Navy strength classifica-

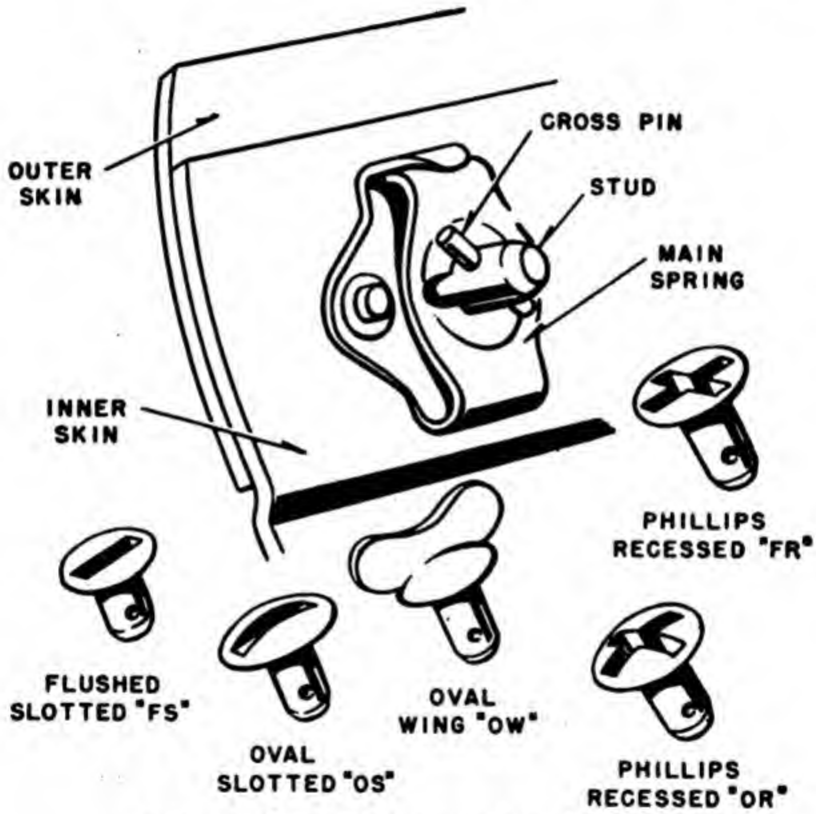


Figure 110.—Shakeproof fasteners.

tion of 500 pounds. If this third number were a 7 it would stand for the 700 pound classification.

The 6 in the above sample means the total sheet thickness which the Shakeproof Fastener will take —in this case .055 inch to .064 inch. This last figure in the symbol represents MAXIMUM sheet thickness. The minimum sheet thickness is always .010 in. less. (This figure in the symbol determines the location

of the drilled hole for the cross pin.) Standard range of sheet thickness for these fasteners is from .040 to .250 inch. The last zero is always omitted in the symbol. Thus you might have for the fourth part of your symbol any figure from 4 to 25.

Here's how to install a Shakeproof fastener.

1. Locating from suitable mark or pilot hole, drill or punch clearance hole in inner sheet.

For Oval Head Type

Provide
.500
.516 Diameter Hole

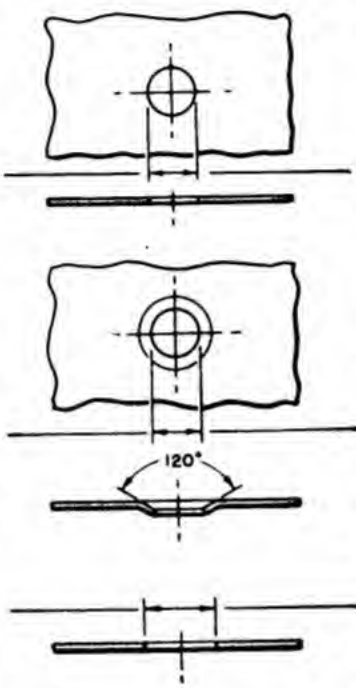
For Flush Head Type

Provide
.500
.516 Diameter Hole

Dimple with Shakeproof 120° dimpling tool where inner sheet does not exceed .050, unless nested dimples of inner and outer sheets cause interference in main spring mounting.

.705 Minimum Dia.
.720 Maximum Dia.

Where outer dimpled sheet exceeds .050 provide undimpled clearance hole in inner sheet.



For Oval Head Type

Provide
.562
.578 Diameter Hole

For Flush Head Type

Provide
.562
.578 Diameter Hole

Dimple with Shakeproof 120° dimpling tool where inner sheet does not exceed .060, unless nested dimples of inner and outer sheets cause interference in main spring mounting.

.795 Minimum Dia.
.810 Maximum Dia.

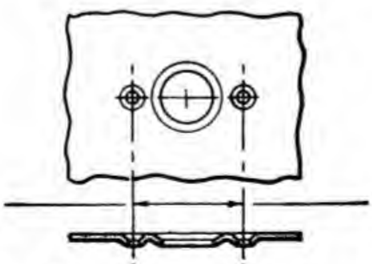
Where outer dimpled sheet exceeds .060 provide undimpled clearance hole in inner sheet.

Figure 111a.

2. Drill or punch 2 holes and dimple for 1/8 — 100° countersunk rivets (AN426-4).

1″ Centers

Machine countersink rivet holes if inner sheet thickness exceeds .030.



1⅜″ Centers

Machine countersink rivet holes if inner sheet thickness exceeds .060.

3. Rivet Main Spring in place.

4. Locating from suitable mark or pilot hole, drill or punch clearance hole in outer sheet.

Figure 111b.

For Oval Head Stud

.261 Minimum
Diameter Hole

For Extra "Float"

Up to .312 Maximum
Diameter Hole

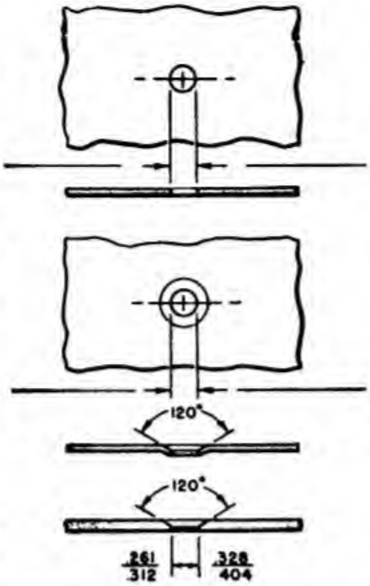
For Flush Head Stud

$\begin{matrix}.261\\.266\end{matrix}$ Diameter Hole

Dimple with Shakeproof 120° dimpling tools for thicknesses not exceeding .100.

or

Machine Countersink when outer sheet thickness exceeds .100".



For Oval Head Stud

.328 Minimum
Diameter Hole

For Extra "Float"

Up to .404 Maximum
Diameter Hole

For Flush Head Stud

$\begin{matrix}.328\\.332\end{matrix}$ Diameter Hole

Dimple with Shakeproof 120° dimpling tools for thicknesses not exceeding .100.

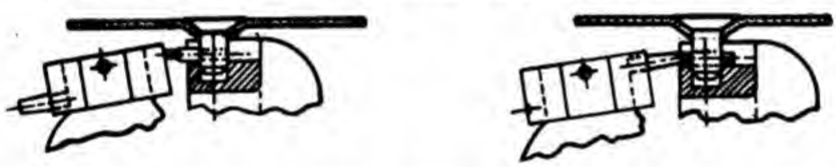
or

Machine Countersink when outer sheet thickness exceeds .100".

NOTE: In special applications (plywood, etc.) or where adaptions are to be made to existing tooling, grommets may be supplied.

5. With stud in installed position (through outer sheet) finger insert cross pin in hole in stud shank.

6. Press fit cross pin in stud with special Shakeproof pliers.



6a. If it is desired to remove or exchange stud, then cross pin may be removed with special plier jaw attachment. In this operation, effort is reduced by slightly opening the plier jaws with the toggle screw.

Figure 111c.

WHERE TO USE CAMLOC FASTENERS

You will find Camloc fasteners handy for securing cowl panels and access doors which must be opened often. Figure 112 illustrates some typical uses.

These fasteners are flush mounted, light in weight. They require just a quarter turn to lock or unlock. You can use them on both straight and curved sheets of metal, plastic, or plywood.

There are two sizes of Camloc fasteners at present, the large size with a ⅜ inch diameter stud head, and a

smaller size with a $\frac{3}{16}$ inch diameter stud head. The large size is made in three parts—stud assembly, grommet, and cam collar. You'll find just two parts in the small size—the stud assembly and cam collar. The

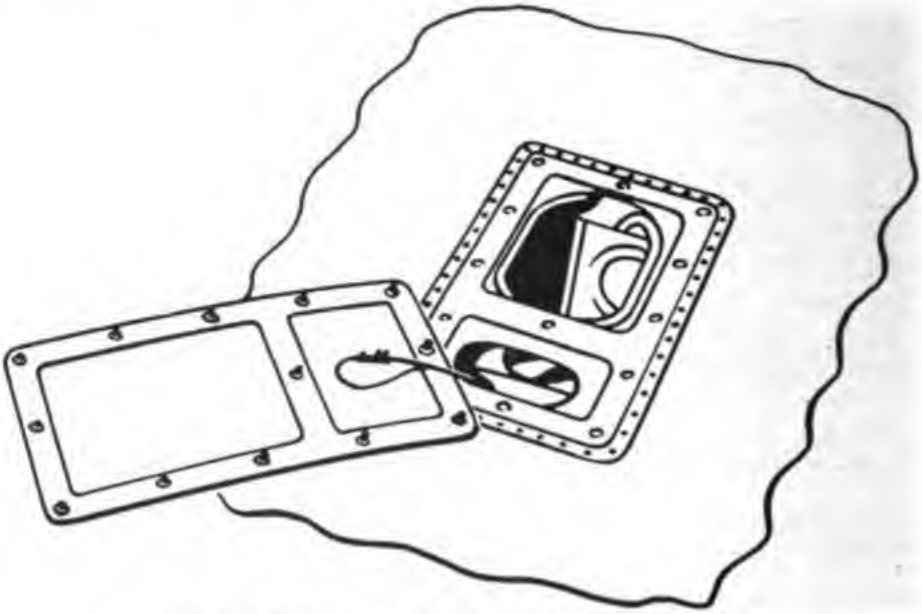


Figure 112.—Use of Camloc fasteners.

grommet is combined with the stud. Take a look at these parts in figure 113.

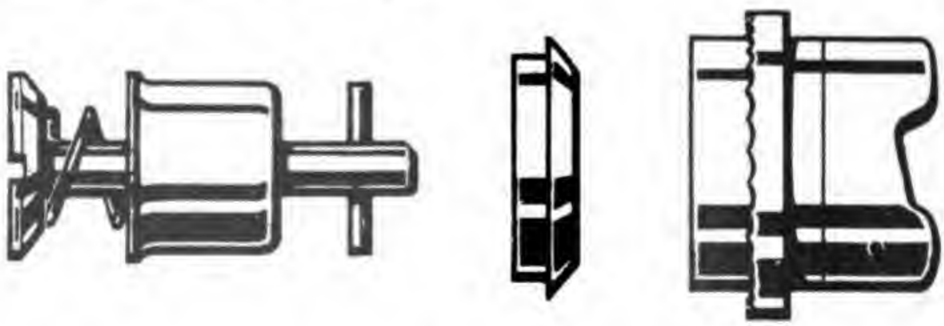


Figure 113.—Camloc parts.

Break down the Camloc fastener and here's what you find.

CAM COLLAR—This is a forged aluminum receptacle. It is permanently attached to the aircraft structure in

a hole which has either been dimpled or countersunk so that the cam collar does not extend above the mounting surface. The cam collar is made with skirts of different lengths for flanging into various thicknesses of materials. Each length has its own specification number.

GROMMET—The flanged ring which is permanently fastened to the panel, cowling, or other removable member of the aircraft assembly. It is furnished in various lengths, each of which has its own specification number. The grommet is omitted from the design of the smaller type of fastener, where the stud assembly is flanged directly into the removable panel.

STUD-ASSEMBLY — This consists of stud, cross-pin,

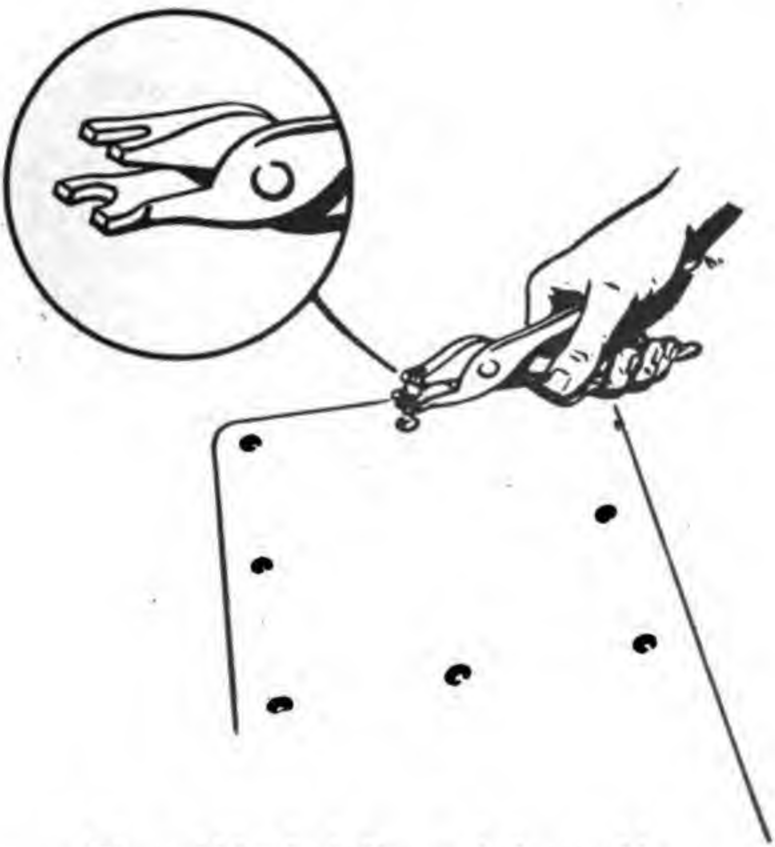


Figure 114.—Installing a stud assembly.

spring, and spring cup. It is permanently assembled at the factory and should never be disassembled. The assembly is so designed that it can be quickly inserted into the grommet by compressing the spring. Once

installed in the grommet, the stud assembly can't get out until the spring is again compressed.

HOW TO INSERT STUD ASSEMBLY

It is simple to insert the stud assembly into the grommet. Just compress the spring of the stud assemblv with pliers, and push the stud through the grommet. There are special Camloc pliers for this job, or you can easily make a little metal strip extractor to do the trick. See figure 114.

You can compress the spring with ordinary pliers, although it's easier to use the special tools. Always use the shortest stud assembly that will lock and unlock without binding.

HOW TO SELECT PROPER SIZE

You should select the grommet and collar according to the thickness of the sheets in which they are installed. The stud should be selected according to the total thickness of sheets to be fastened, including the thickness of any "air spaces" formed by dimpling the sheets around the hole. Read the chart showing the sizes to use, according to sheet thickness.

LARGE SIZE CAMLOC

(3/8 inch Diameter Stud Head)

Name of Part	Mfr. 4002 Dash No.	Sheet Thickness
Collar	—504	(Inner) .050 to .070
Collar	—524	(Inner) .050 to .070
Grommet	—B	(Outer) .025 to .031
Grommet	—C	(Outer) .032 to .048
Stud	—1	(Total) .051 to .080
Stud	—2	(Total) .081 to .110
Stud	—3	(Total) .111 to .140
Stud	—4	(Total) .141 to .170
Stud	—5	(Total) .171 to .200
Stud	—6	(Total) .201 to .230
Stud	—7	(Total) .231 to .260

SMALL SIZE CAMLOC

($\frac{3}{16}$ inch Diameter Stud Head)

Name of Part	Mfr. Part No.	Outer Sheet Thickness	Total Sheet Thickness
*Collar	2002-502		
Stud	2500A-1	.040 to .049	.070 to .090
Stud	2500A-2	.040 to .049	.100 to .129
Stud	2500A-3	.040 to .049	.130 to .159
Stud	2500A-4	.040 to .049	.160 to .189
Stud	2500A-5	.040 to .049	.190 to .219
Stud	2500A-6	.040 to .049	.220 to .249
Stud	2500C-1	.060 to .069	.070 to .099
Stud	2500C-2	.060 to .069	.100 to .129
Stud	2500C-3	060 to .069	.130 to .159

***Where inner sheet thickness exceeds .064, this collar may still be used if sheet is countersunk or counter-bored.**

CHAPTER 5

STRUCTURAL REPAIRS

LOOK BEFORE YOU LEAP

Every thin sheet metal aircraft structure has been DESIGNED TO PERFORM A SPECIFIC FUNCTION OR TO SERVE A DEFINITE PURPOSE. In the repair of aircraft the prime objective is to restore the injured or damaged part to its original condition. Often, replacement is the only way in which this can be effectively done. When it is possible to repair successfully a damaged part, however, the first thing you have to do is to study it carefully and fully understand its purpose or function.

Strength, for instance, is the principal requirement in the repair of certain structures, while in other structures entirely different characteristics may be desired. For example, fuel tanks, seaplane floats, and hulls must be protected against leakage, but cowlings, fairings, and similar parts require totally different properties—neat appearance, streamlined shape and accessibility, for instance.

You know the saying, "Fools rush in where angels fear to tread." Make sure it doesn't apply to you. Study your job carefully. Determine the functions of the damaged part. Then plan the best way to restore that part to its original efficiency.

You will want to use a watertight patch for repairing surfaces that come in contact with water—such as floats and hulls. These patches must be made so that they are absolutely waterproof. A LEAKY float or hull means an UNSAFE airplane.

There are two general types of patches—lap and flush. The lap patch is an external one. That is, a piece of aluminum is simply lapped over the damaged opening. In the flush patch the material is inserted into the hole so that its surface is FLUSH with the skin being repaired.

The material you use for watertight patching should be an alloy of the same type and temper as the skin

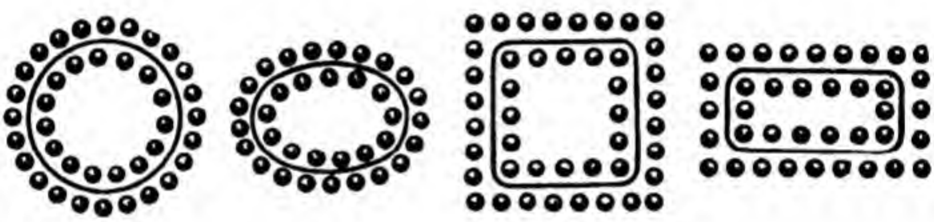


Figure 115.—Shape of patches.

being repaired and should also be one thickness heavier. For the flush type, the patch itself should be of the same thickness as the part being repaired but the REINFORCING PLATE OR RING which is used on the inside of the flush patch, should be one thickness heavier. Both the flush and lap type of patches should be cut and finished to size, the holes drilled, and then primed before assembling.

The patch may be round, oval, square, or rectangular as in figure 115.

Remove the damaged material, leaving a symmetrical hole and make the patch of the same shape as the hole. If the hole and patch are rectangular, the corners should be well-rounded.

In general, FLUSH patches are used BELOW the water

line and LAP patches, ABOVE the water line. Flush patches make it possible to beach planes on sand, where a lap patch would tear.

To be watertight, seams on floats or hulls must be carefully lined with a sealing material. Usually the sealing material is canton flannel or linen that has been impregnated with some type of sealing compound like zinc chromate or soya bean oil. These substances will not harden and water won't separate them from the fabric.

RIVETS FOR PATCHES

There are no specific rules which will apply to every case or type of riveting. But here are some guides for you to use in selecting rivets and in spacing them on watertight patches.

The SIZE of the rivets should be, as far as possible, the same as that of the original rivets in the part being repaired. As a general rule they should never be less than $\frac{3}{32}$ inch in diameter, nor less than the thickness of the thickest sheet through which they are driven. The maximum diameter should not exceed $2\frac{1}{2}$ to 3 times the thickness of the thickest sheet through which the rivet is driven.

When you are replacing rivets you may drill the holes out so that the next larger size can be used, but be sure that the minimum edge distance is maintained.

The absolute minimum distance from the center of the rivet to the nearest edge of the sheet must be twice the diameter of the rivet. For countersunk rivets it should be $2\frac{1}{2}$ times the diameter. Rivet holes tear out under loading when this rule is violated. Don't YOU violate it.

Try to keep the edge distance as close to the minimum as possible, because the edge of the sheet will tend to lift if this distance is exceeded very much.

Rivets must not be TOO closely grouped, because then the stressed area becomes too small or the cross section is reduced too much by the rivet holes. The

maximum spacing BETWEEN rivets should be small enough, however, so that the portion of the plate between rivets will not buckle under compression loads. This distance, for a single row of rivets, should never be less than three times the rivet diameter.

Where there are two rows of rivets, the outer row should be staggered with the inner row of rivets. The distance between rows should be approximately 75 percent of the pitch of the first row of rivets. (Pitch means the center to center distance between rivets.)

HOW TO MAKE A LAP WATERTIGHT PATCH

Suppose that the damage is confined to a small area and is located in a spot which is easy to get at.

The first step in its repair is to clean up the tear or hole by removing or bumping out all dents and irregularities.

Then trim out the damaged area symmetrically so that there will be no weakened metal or sharp corners. Remove the paint from the trimmed hole for a distance back from the edge of at least ¾ inch. Take a final look around the hole for further cracks. If none are present, smooth the edges of the hole with a file.

Now select patching material of the same alloy and either the same or greater thickness as that of the skin being repaired, preferably greater.

The quickest way to transfer the pattern of the hole to the patch material is to SCRIBE the outline of the hole upon it. To do this, place a piece larger than that needed for the repair over the hole. Then scribe the required outline. Use a small piece of scrap metal taped to the approximate center as a dead center for the dividers to prevent scarring the repair material. If the surface of the skin has a contour, the patch should conform to it. If the patch is NOT formed to match the contour of the skin, the finished repair has a tendency to "oilcan" that area—especially if the patch material is of a thicker gage than the original skin.

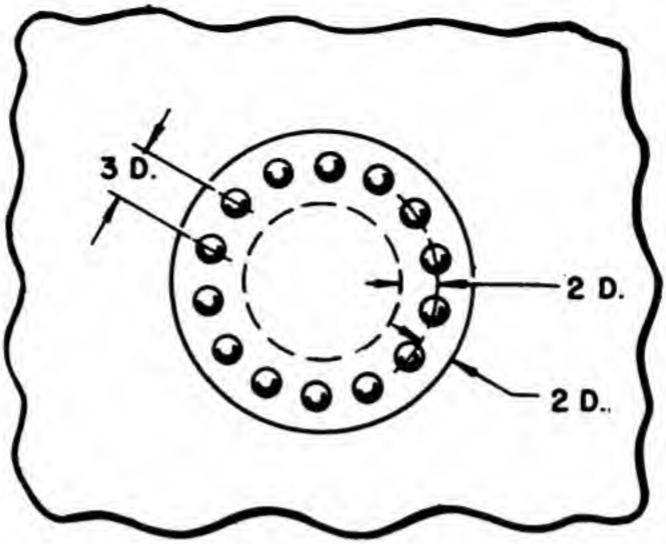


Figure 116.—Amount of overlap for one row of rivets.

The amount which the patch should overlap the edges of the hole depends upon the size of the opening being repaired, because you must allow room for rivets. As a general rule, for a hole approximately 1½ to *2* inches, a patch having a single row of rivets is sufficient. You will need to allow less overlap for this size of hole than you would for a larger hole whose patch must accommodate TWO rows of staggered rivets.

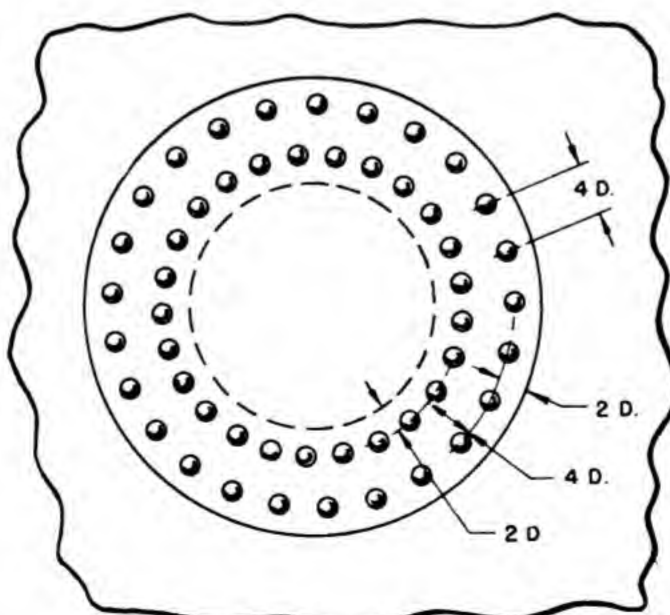


Figure 117.—Overlap to accommodate two rows of rivets.

If the patch is small, the amount of overlap can easily be determined by figuring the proper edge distance for the rivets. Thus, if the hole is two inches, the patch should overlap approximately ½ inch if ⅛ inch diameter rivets are used. This provides a two diameter edge distance on either side of the row of rivets as in figure 116.

The same rule can be followed in figuring the correct overlap for a double row of rivets. For instance on a patch covering a four inch hole, the overlap should be about one inch. Assuming that you use ⅛ inch diameter rivets, this provides an allowance of two rivet diameters on either side of the double row of rivets, plus a space of four rivet diameters between the rows. Figure 117 shows how these proportions would work out.

You should bevel the edges of the lap patch down to approximately HALF the metal thickness. The edges should also be crimped to about 15° to provide a tighter fit for the patch. You can do the crimping on either a crimping machine or with a mallet. Do the beveling with a file. Figure 118 (*A*) shows the assembled patch while (*B*) and (*C*) show how beveling and crimping are done.

After you have drilled the rivet holes in the patch, place the patch over the opening and drill two or three matching rivet holes in the skin. Now insert Cleco fasteners or sheet metal screws to hold the patch temporarily in place. Then drill the remaining holes, take off the patch and eliminate all the burrs.

The next step is to fix up the waterproofing material such as canton flannel impregnated with soya bean oil compound or zinc chromate paste.

Now cut a piece which will extend slightly BEYOND the edge of the patch. Impregnate it with sealing compound; place it over the hole, and then fit the patch into place. Now insert machine screws in every third or fourth rivet hole. Use nuts on the machine screws, drawing the patch tight enough so that sealing compound is squeezed out around the entire patch. Be

sure to make it tight or the patch will leak. Cleco fasteners are not recommended for holding the patch. They don't exert enough tension to squeeze out excess sealing compound.

Now drive rivets in the open holes—that is, those holes which do not have machine screws in them. Then remove the screws from the remaining holes and replace them with rivets. It is a good idea to put some sealing compound under the head of each rivet before

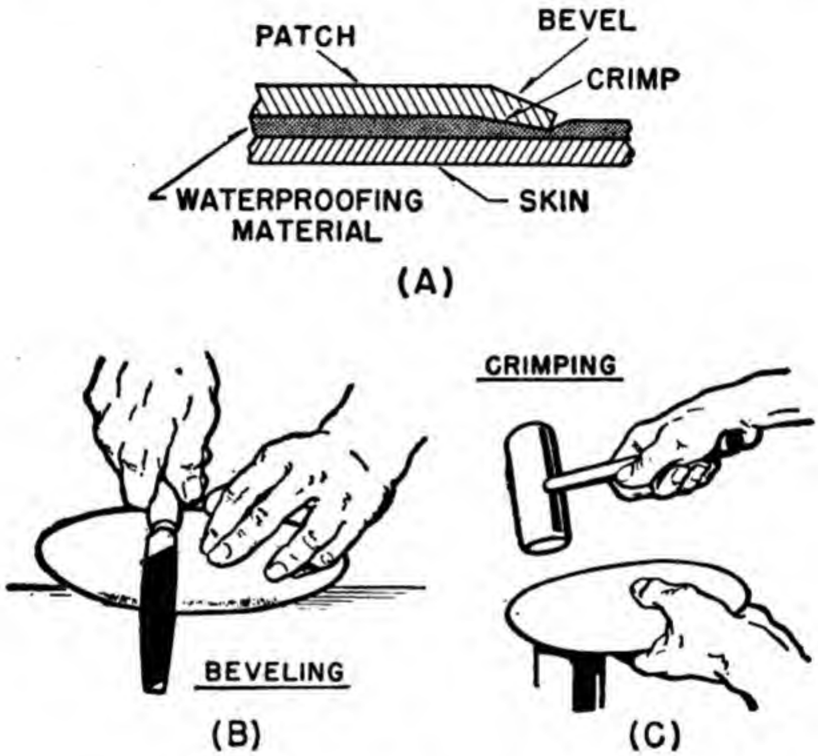


Figure 118.—Crimping and beveling.

you drive it. This practice should be adhered to ESPECIALLY when the rivets are 5/32 inch and larger, or when you are using countersunk rivets.

Now clean up the entire patch by cutting away the excess waterproofing material from the edges, but be careful not to scratch the skin and give corrosion a chance to set in. You can wash away the excess sealing compound with carbon tetrachloride, kerosene, or any other liquid which won't remove the paint.

After you have cleaned the patch inside and outside, apply an additional coat of zinc chromate primer followed by a number of coats of the required finish.

HOW TO MAKE A FLUSH TYPE WATERTIGHT PATCH

Take off the paint from all sides of the damaged area and trim the edges to eliminate all raggedness and radiating cracks. When you get through you should have a symmetrical opening. Then file the edges smooth.

When you use a flush patch you must also use a reinforcing plate or ring on the underside of the opening

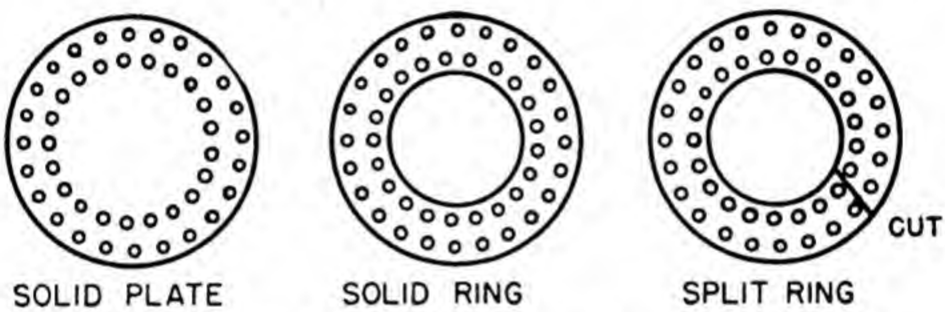


Figure 119.—Reinforcing plate and rings.

to serve as a support. This reinforcement may be either a solid piece of metal extending across the entire opening as in the first drawing in figure 119, or it may be a ring of sufficient area to hold the patch, as in the second and third drawings of figure 119. A split ring, like that in the third drawing, is necessary where it is impossible to reach the skin from the underside.

The reason the reinforcing ring must be split for inaccessible sections is, of course, due to the fact that the supporting ring is always LARGER than the opening itself.

There is, however, no hard and fast rule which you can go by in deciding the size of this reinforcing or backup ring. The way to decide upon the size of the ring and the approximate amount of overlap is to take into account the proper EDGE DISTANCE for the rivets as you did in figuring the overlap for a lap patch.

The metal which the ring is made of should be ONE GAGE THICKER than the skin itself. After you have cut out a backup plate or ring, the next thing to do is to cut the flush patch itself. The patch should be of the same material as the skin and must be cut to match the size of the hole EXACTLY.

Now lay out the rivet holes on the backup plate or ring. Then place the backup plate on the outside surface of the damaged skin. Using the drilled holes as guides, drill through the skin. These holes are called pilot holes, and are a few sizes smaller than the rivet to be used.

Next, remove the backup plate and insert it underneath the surface of the skin. Hold it in place temporarily with Cleco fasteners or sheet metal screws and drill to finish hole size for rivets.

Fit the flush patch into position, and drill the necessary rivet holes. Then remove the patch and backup plate, first marking their location so that you can put them back together in the same place.

If countersunk rivets are called for, dimple or countersink the drilled holes.

Next you must prepare the material for the flush type patch in the same manner as that described for the lap patch. There are two ways to do this.

When a solid backup plate is used, the waterproofing fabric may be solid. That is, it may extend over the entire area of the opening as in figure 120 (*A*).

Another method used, shown in 120 (*B*), is to cut out from the CENTER of your piece of waterproofing material, that part which would normally be in contact with the flush patch plate. Then another piece of this material is cut to a size slightly larger than the flush patch plate. It is inserted so that the edges of the fabric are forced BETWEEN the edges of the patch plate and skin.

Now fasten the various parts of the patch plate in place and rivet them together.

SKIN REPAIR

As you learned in the first chapter, modern aircraft construction utilizes MONOCOQUE and SEMI-MONOCOQUE fuselages. In the monocoque fuselage, you remember, there are no lengthwise (longitudinal) members. Reinforcing rings or bulkheads are used at regular intervals

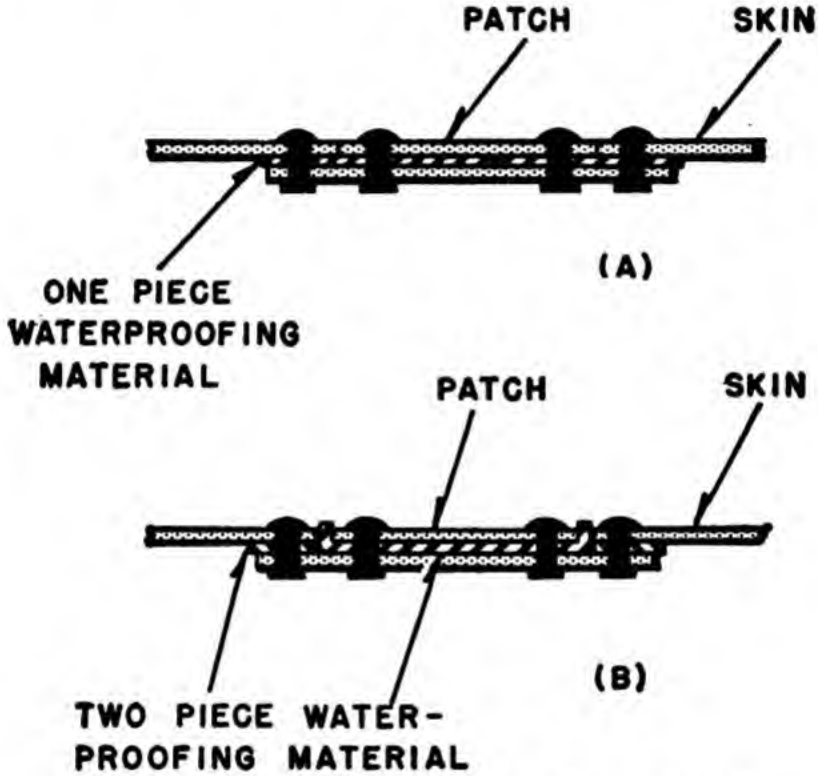


Figure 120.—Inserting waterproofing material.

to provide enough rigidity to maintain the proper shape of the skin. Semi-monocoque construction is similar except longitudinal members called stringers are added across the bulkheads. On both types the outer covering or skin carries HIGH stresses. This is how the term "stressed skin" originated.

Since this outer covering must withstand a great deal of stress, you can easily see that repairs which you make to any part of it must be carefully done so that the damaged section will CONTINUE to bear up under its share of the load.

Skin repairs are divided into two classes — the stressed, and the non-stressed type. Non-stressed repairs are made on engine cowlings, fairings, and other parts that merely serve as streamlining for the various structural parts of an airplane. Since these parts are not intended to carry any load, they are made from non-heat treatable alloys—2S, 3S, and 52S.

Other parts of the skin of metal aircraft are subjected to high stresses. Therefore the repair material must equal the strength of the original material. For repairs on skin subjected to high stress, you will use the heat-treatable alloys, 17ST and 24ST.

STRENGTH OF REPAIRS

Sometimes you may not know just what loads are carried by a part which must be repaired. When this happens, all repaired parts must be AT LEAST AS STRONG AS THE ORIGINAL AREA. In the case of a patch reinforcement or splice, the cross section of the repair part must at least restore the initial strength to the damaged part.

In members subject to compression or bending, it is best to have the splice on the OUTSIDE of the repaired member, because in this way you obtain a greater bending strength. When it is impossible to put the splice on the outside, then the material for the repair should be of the next heavier gage.

Another precaution you must take is to avoid abrupt changes in cross section, in order to eliminate dangerous concentrations of stresses. You can avoid sharp changes in cross section by making small patches round or diamond shape instead of rectangular. For the same reason —that is, dangerous stress concentration—you must avoid sharp corners. All holes should have GENEROUS corner radii.

Once buckled, it is impossible to straighten out any part of a structure so that it can be depended upon to carry its full load again. A BUCKLED MEMBER MUST

EITHER BE REPLACED OR REINFORCED BY A MEMBER OF EQUAL STRENGTH.

MATERIALS FOR REPAIR

At the present time monocoque structures are almost entirely ALUMINUM ALLOY. High strength rolled sheet is used for the skin. Formed sheet is used for bulkhead and ribs. Extrusions or formed angles are used for stringers.

You must choose the material for all replacements or reinforcements to match the material of the airplane being repaired. Table X lists the various alloys and the way they are commonly used in the construction of an airplane.

If it is necessary to substitute a weaker alloy than the original, you MUST use a heavier gage to give equivalent cross sectional strength. On the other hand, NEVER USE A SMALLER CROSS SECTION even when you are using a stronger metal. You should never substitute any other material for Alclad UNLESS special precautions have been taken to prevent corrosion.

RIVETING

Rivet holes should be SLIGHTLY larger than the rivets—from two to five thousandths of an inch larger—to allow for expansion of the rivet shank. If you make the hole too large, the rivet won't expand enough when it is driven to fill the hole. Don't punch holes to size. DRILL them.

It is possible, however, to PUNCH holes, if you PUNCH THEM UNDERSIZE and then ream them to size. Remove all burrs after drilling and clean out the chips from between the plates.

The plates obviously must be held firmly together for riveting in order to maintain their alinement and to prevent the rivet from flashing (bulging out) in the space which is left between the plates if they are not

tightly clamped. The usual procedure is to fasten the plate securely with screws or Clecos every 3 to 5 inches.

After you have driven the rivets in all the free holes, remove the fasteners and drive the remainder of the rivets. The heads of all solid rivets are usually formed on the inside surface of the skin with a plain dolly bar. This produces a flat head which must have the following proportions—

The flat, bucked head must have a height equal to at least half the diameter of the rivet, and its width must equal 1½ diameters of the rivet. The length of the rivet required to form a bucked head of these proportions varies with the thickness of the skin into which it is driven and with the size of the hole. A common rule is to pick a rivet whose length is equal to the combined thickness of the metal plus 1½ times the diameter of the rivet.

The rivet size should be the same as the original rivet in the part being repaired. As in riveting flush type patches, your rivets should never be less than 3/32 inch in diameter,—or not less than the thickness of the thickest sheet through which they are driven. This is a minimum. The maximum diameter of the rivet should not exceed 2½ to 3 times the thickness of the thickest sheet through which the rivet is driven. The reason for setting a maximum diameter of rivet is, as you know, to prevent buckling the thin sheets with the high pressure necessary to drive a large diameter rivet.

Holes that are slightly oversize MAY be used IF oversize rivets are driven in them and if the minimum edge distance is kept.

You should duplicate the original spacing of the rivets in the part being repaired, unless it is necessary for some reason to put them closer together. The ABSOLUTE MINIMUM edge distance measured from the center of the rivet to the nearest edge of the sheet must be twice the diameter of the rivet.

For countersunk rivets, this absolute minimum is 2½ times the diameter of the rivet.

TABLE X

TENSILE STRENGTH OF ALUMINUM ALLOY SHEET

Commercial Designation	Navy Spec.	Army or Navy Tensile Strength PSI	Allowable Bearing PSI	Remarks
2S ½ H	47A2 ½H	N 16,000	....	Do not use—replace with 3S ½ H
3S ½ H	47A4 ½ H	AN 19,500	....	Welded tanks
4SO	47A9 Temp. A	AN 29,000 Max.	....	Spun parts
17S Alclad 17S	47A3 47A6	AN 55,000 AN 50,000	75,000 68,000	Do not use—replace with 24S
24SO	47A10 Cond. A (Annealed)	AN 35,000 Max.	....	Formed structural parts, ribs, bulkheads, etc.; must be heat-treated to 24ST after forming
24ST	47A10 Cond. I(H.T.)	AN 62,000	90,000	Skin and parts bent not formed
24SRT	47A10 Cond. T.R. (H.T. & R.)	AN 65,000	....	Highly stressed flat skin or web
Alclad	....	AN 32,000	....	Same uses as 24S above. Better resistance to corrosion; lower strength
Alclad 24ST	47A8 Cond. T(H.T.)	AN 56,000	82,000	
Alclad	47A8 Cond. T.R. (H.T. & R.)	AN 58,000	....	
52SO 52S ½ H	47A11 Temp. A 47A11 Temp. ¼ H	AN 31,000 AN 31,000	....	Formed non-structural parts. Cowling and fairings

You should space the rivets as close as possible to the minimum edge distance, because the edge of the sheet will tend to lift if the rivets are spaced a distance much greater than the minimum.

Minimum spacing BETWEEN rivets is determined by the space required to drive each rivet without interference. Three diameters measured from center to center of the rivets is probably the minimum. You should be careful, however, not to group rivets too closely in order to avoid reducing too much either the stressed area or the cross section of the sheet.

Rivets should always be STAGGERED in order to keep to a minimum the number of rivets located in a line at right angles to the principal stress. The maximum spacing between rivets should be small enough to prevent buckling of the sheet in the space between rivets when compression loads are applied. Maximum spacing is usually a distance not greater than 24 times the thickness of the thickest sheet being riveted. A good average is 6 to 8 times the diameter of the rivet being used. In general, the spacing is regulated by the unit stress of the structure.

REPAIRING SMALL CRACKS IN NON-STRESSED SKIN

Drill a small hole, $\frac{3}{32}$ or $\frac{1}{8}$ inch, at each end of the crack to prevent the crack from spreading.

Cut a piece of reinforcing material of the same type and thickness as the original sheet. Cut it large enough to extend at least $\frac{3}{4}$ or 1 inch beyond all sides of the crack. The shape of this patch will depend upon the pattern and location of the crack. Patches are usually square, circular, rectangular, or diamond shaped. Figure 121 shows patches of these shapes.

After the patch is cut to shape, round its corners and lay out on it the locations for the rivet holes. Then drill a few holes in the patch plate to serve as guides for drilling the holes in the skin which it will cover.

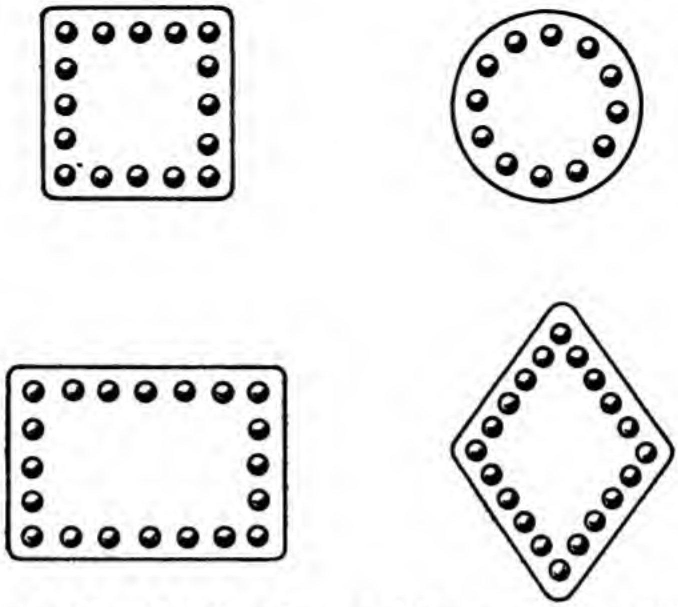


Figure 121.—Patches for repairing non-stressed skin.

Fasten the patch temporarily with sheet metal screws or Clecos and drill the remaining holes.

Now remove the patch and clean off all the burrs. Then apply a coat of zinc chromate primer to the underside of the patch and to the surface of the skin.

Replace the patch and rivet it in place. The best method is not to attempt to drive all the rivets one after another in a single row, but rather to drive a rivet first on one side of the patch and then on the opposite side.

REPAIRING SMALL CRACKS IN STRESSED SKIN

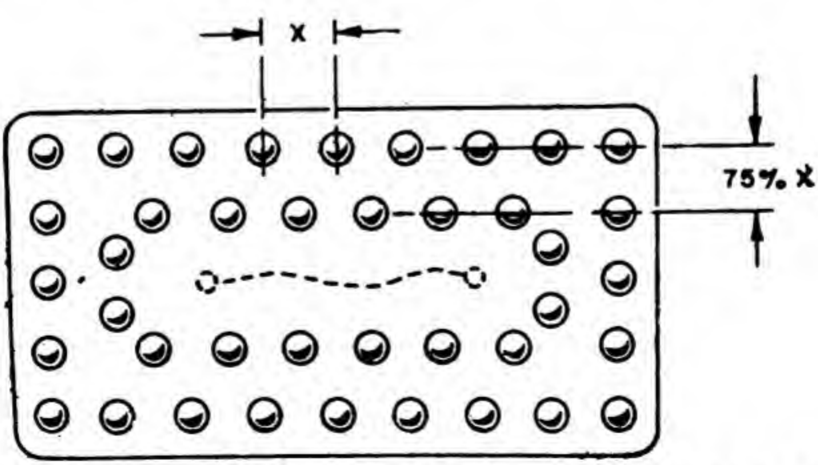
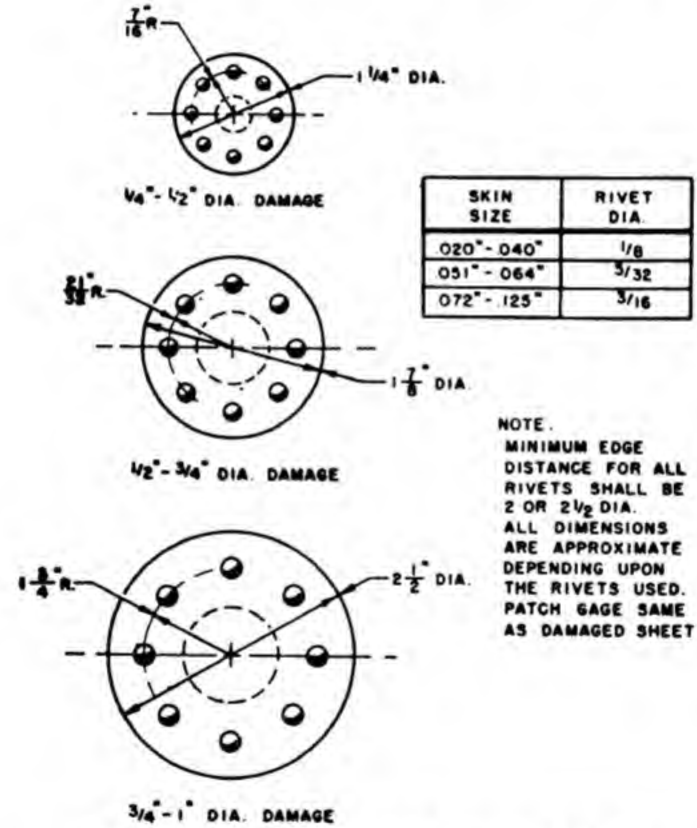


Figure 122.—Patch for repairing cracks in stressed skin.

The repair of cracks in stressed skin requires practically the same system as that for cracks in non-stressed skin. A patch on stressed skin, however, requires more rivets. Attach the plate with rivets spaced approximately ¾ inch apart in two staggered rows which are spaced at intervals representing about 75 percent of the rivet spacing in the first row, as in figure 122.

REPAIRING HOLES

You can repair holes in either stressed or non-stressed



SKIN SIZE	RIVET DIA.
.020"-.040"	1/8
.051"-.064"	5/32
.072"-.125"	3/16

Figure 123.—Lap patch for small hole.

skin which are less than 3⁄16 inch in diameter by filling them with a rivet. Drill or file the hole until it is round and then drive a rivet of the proper size into it to plug it up.

To repair holes larger than 3⁄16 inch but less than 1 inch in diameter in either stressed or non-stressed

skin, you must use a LAP PATCH like that shown in figure 123.

Holes in STRESSED SKIN may be of either the OPEN or CLOSED type. An open hole is one which can be reached from both sides of the damaged surface. A closed hole is one which is not accessible from the in-

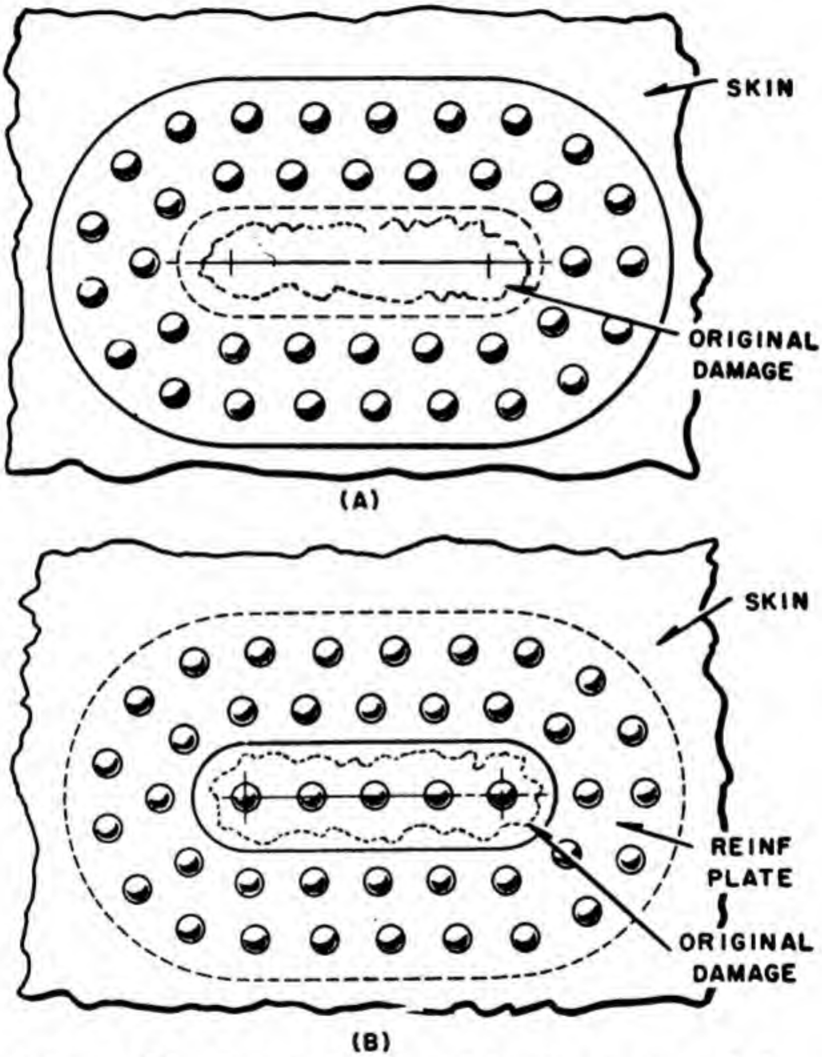


Figure 124.—Lap and flush patches for an open hole.

side. Patches for either type of hole may be of the lap or flush type. In either case, use rivets which have the same head shape as those originally used on the skin.

Figure 124 (*A*) shows the lay-out for a lap patch, while 124 (*B*) shows the lay-out for a flush patch. Both of these are for use on an OPEN HOLE in stressed skin.

In patching an open hole, first cut away the sharp and ragged edges.

Next cut the patch from material either of the same thickness as the original skin panel or of one gage heavier thickness. If you are going to use a flush patch, check back to the section on repair of these patches to find out how to prepare the backup plate.

HOW MANY RIVETS DO YOU NEED?

Smooth, flat aluminum sheet will carry only a small compressive load. It is usually designed to carry a tensile load (that is, offer a resistance to tearing).

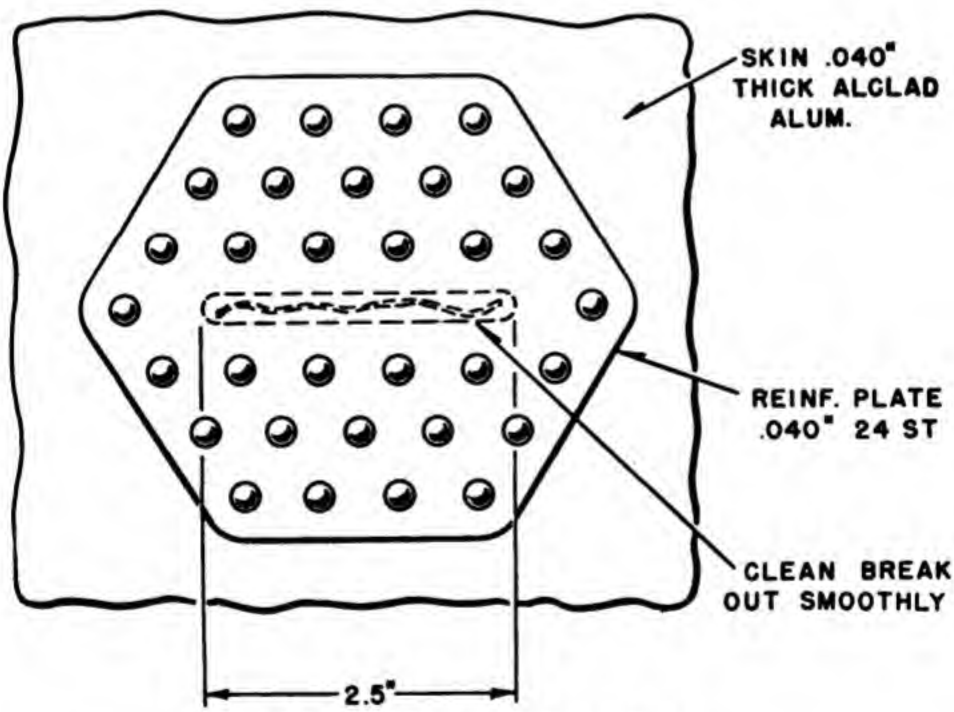


Figure 125.—Rivet spacing.

The skin is designed to carry a maximum allowable load in tension of approximately 43,600 pounds per square inch (psi). This figure takes into consideration a loss in area caused by drilled rivet holes. Generally, all smooth skin is said to be under this stress.

Rivets holding a patch should be spaced at intervals

of approximately 6 times the diameter of the rivet shank. Never space them at intervals of less than four diameters. This would result in a concentrated stress area.

For a CLOSED HOLE, when the inside of the skin is not accessible, for instance in the closed section of a wing panel, you make repairs in much the same way as you do on an open hole EXCEPT that special rivets or screws must be used to close the hole from the outside.

Suppose that you want to remove a section of the skin in order to have access to the interior for repair or inspection. How will you replace it? You can use a patch—of either the flush or lap type.

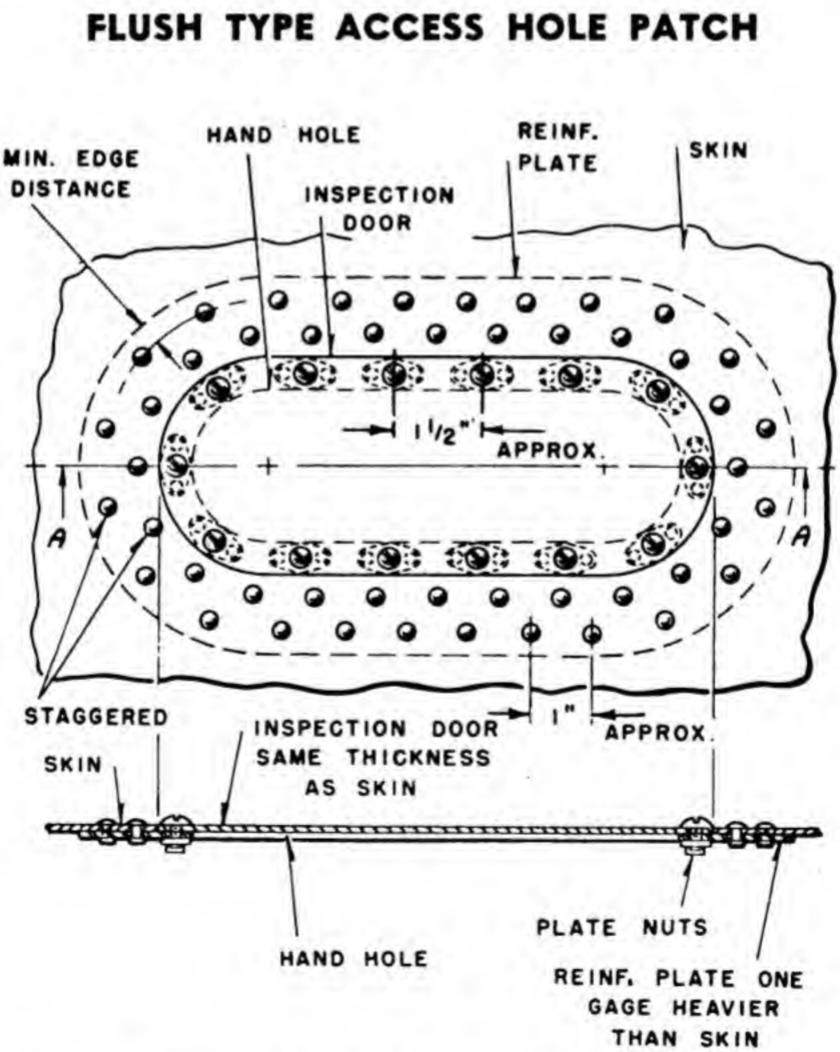


Figure 126.—Installation of a flush type access patch.

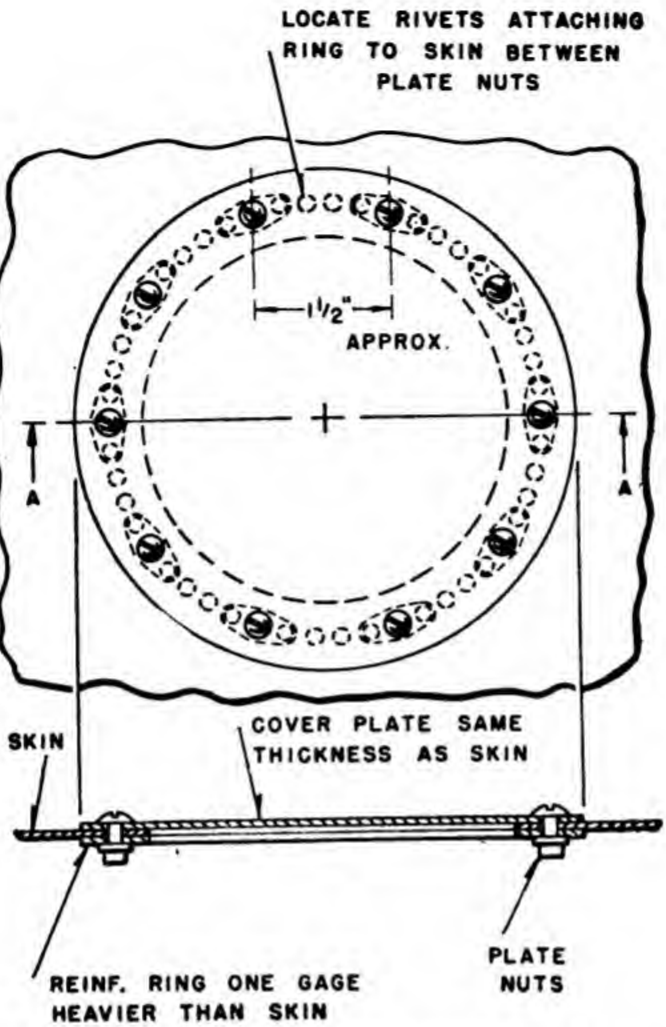


Figure 127.—Lap type access patch.

This type of hole is most satisfactory for general use on an airplane. The hand hole is cut as shown in figure 126 and is reinforced with a backing plate, installed on the INSIDE of the skin. This plate is usually one gage heavier than the skin itself.

You must rivet nut plates to the inside edge of this backing plate, which is fastened to the skin with rivets spaced approximately 1 inch apart. The rivets are spaced in two staggered rows at least ¼ inch from the edge as in figure 126.

The inspection door, which is cut to fit the hand hole in the skin, may be of the same gage as the skin material. You must drill it to match the nut plates.

LAP TYPE ACCESS HOLE

As an alternative to the flush type patch, you may use a lap-patch like that in figure 127. Cut a circular hole in the skin and reinforce it on the inside with a ring ¾ inch wide. Then rivet No. 10-32 nut plates and screws, spaced approximately 1½ inch apart, to the ring.

After splitting the ring so that it can be inserted into the hole, rivet it to the inside of the skin with two rivets between each nut plate. Drill the cover plate to match the nut plates.

STRINGER REPAIR

Extruded or formed angle splices are used to repair stringers, stiffeners, and other structural parts of an aircraft.

Stringers, in a semi-monocoque structure, are used

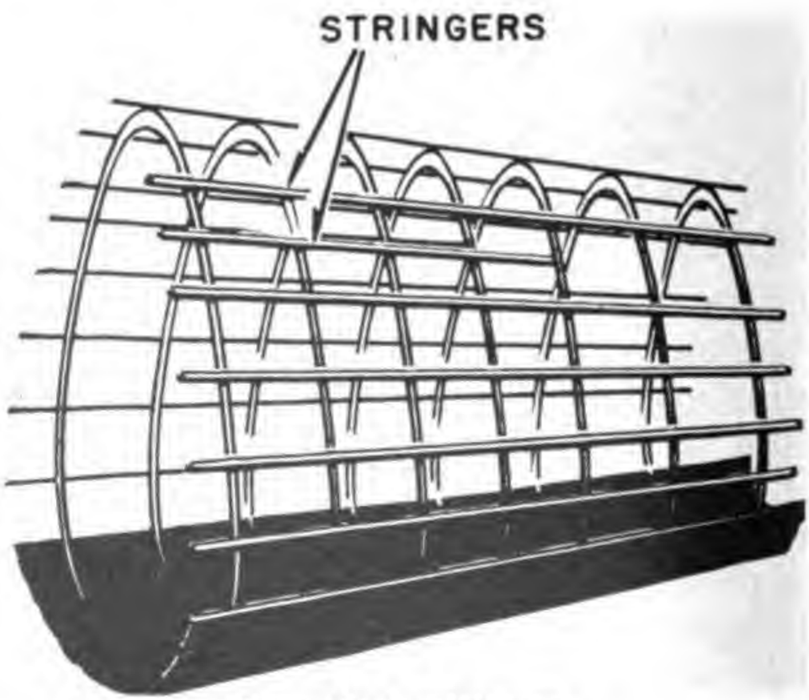


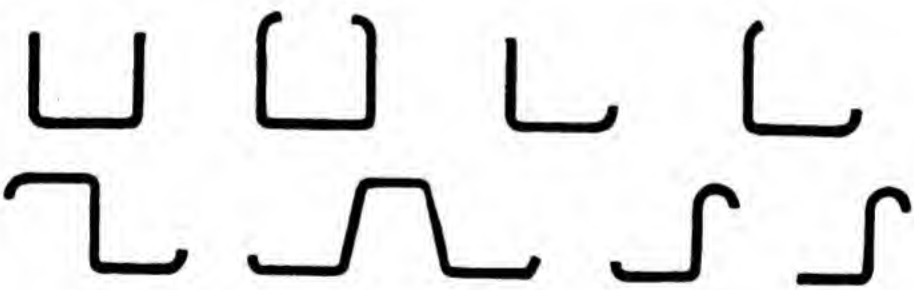
Figure 128.—Stringers.

throughout the parts of the plane as lengthwise structural members to connect the bulkhead rings or ribs

and to TRANSMIT stress. Stringers are used in the wings, fuselage, landing gear, fins, rudders, stabilizers, elevators, engine nacelles, and cowling of a plane. Figure 128 shows the close-up of a stringer.

Extruded angles are most generally used for stringers because of their high strength-to-weight ratio. Extruded shapes are made by a process very similar to

EXTRUDED STRINGERS



FORMED STRINGERS

Figure 129.—Types of stringers.

the way your toothpaste is shaped as you force it from the tube. An extruded angle stringer is produced by forcing hot metal through a die in which there is an opening which corresponds to the desired cross section of a stringer. This process frequently uses the metal more efficiently than the rolling process.

Extruded angle stringers are easy to assemble. Since they require high strength, they are made of 24ST

alloy. Figure 129 shows various shapes of extruded angle stringers.

Sometimes, however, stringers are not made of extruded angles. In these instances, they may be made of numerous types and shapes formed on brakes or various combinations of die presses. They are made from annealed aluminum alloy which has to be heat-treated after forming in order to maintain the maximum strength of the stringers. These are shown also in figure 129.

KINDS OF STRINGER DAMAGE

The damage which stringers may sustain can vary widely from that which might be called negligible to that which is so extensive that the entire stringer or a portion of it has to be cut out and replaced.

Stringers may fail because of vibration. They may be weakened by corrosion or they may be severely twisted or torn by shrapnel or by a collision. You may have to repair stringers in places that can only be reached through an inspection door, lightening hole or by removing a section of the skin.

It's extremely important that you use good judgment in determining the extent of the damage and the method of repair BEFORE actually beginning work. The repairs must be properly made if the original strength of the structure is to be kept.

For your purposes there are two kinds of stringer damage.

NEGLIGIBLE DAMAGE. This is any smooth isolated dent (not more than 1/16 inch in depth) which is free from cracks, abrasions and sharp corners. Such dents may be filed smooth. If no two stringers in the same section are affected you won't need to do anything more than file the dent.

REPAIRABLE DAMAGE. All nicks, cracks, and ruptures should be repaired with SPLICES if they don't fall in the above classification. Lengths of material

which are similar or identical to the damaged stringers are used for these splices to replace the damaged portions or to reinforce the added sections.

REPAIRING CRACKS

If the stringer is bent or dislocated, the bent portion is considered the length of the damage. You must

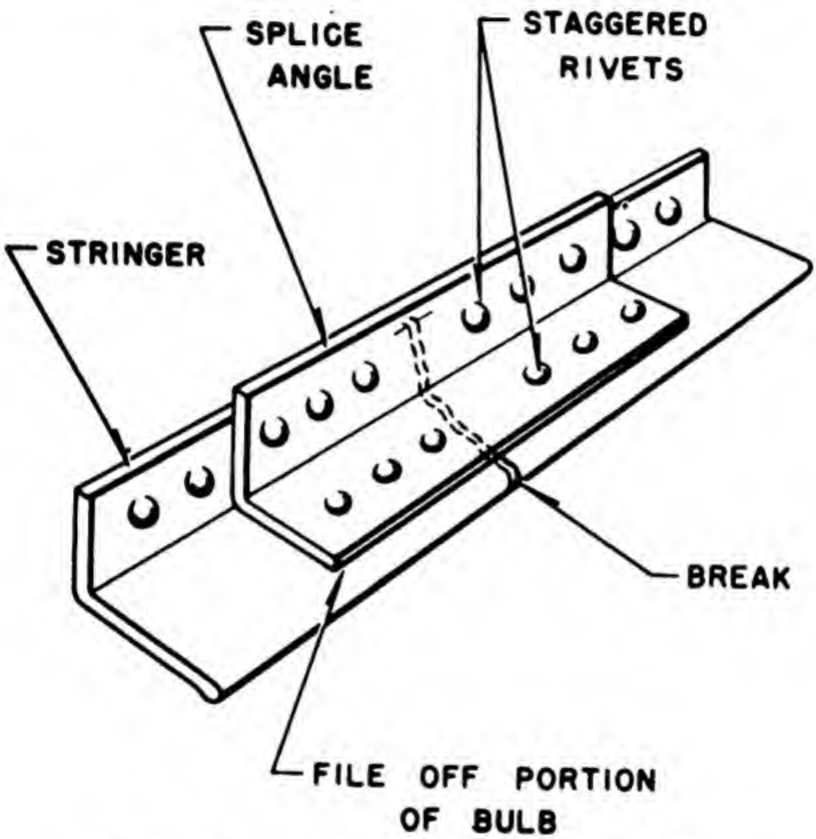


Figure 130.—Repair of bulb extrusion angle.

remove it and replace it with a filler. If the stringer is cracked, it can be repaired by applying a reinforcement which must have the same cross section as the stringer itself. Figure 130 shows how to repair cracks in bulb extrusion angles. An alternate method is shown in figure 131 where you will notice that the reinforcement splice is not riveted to the skin, but is set back from it about $\frac{1}{16}$ inch. Use this alternate method when

you want to avoid rivets in the skin because they would interfere with some other structural member or skin.

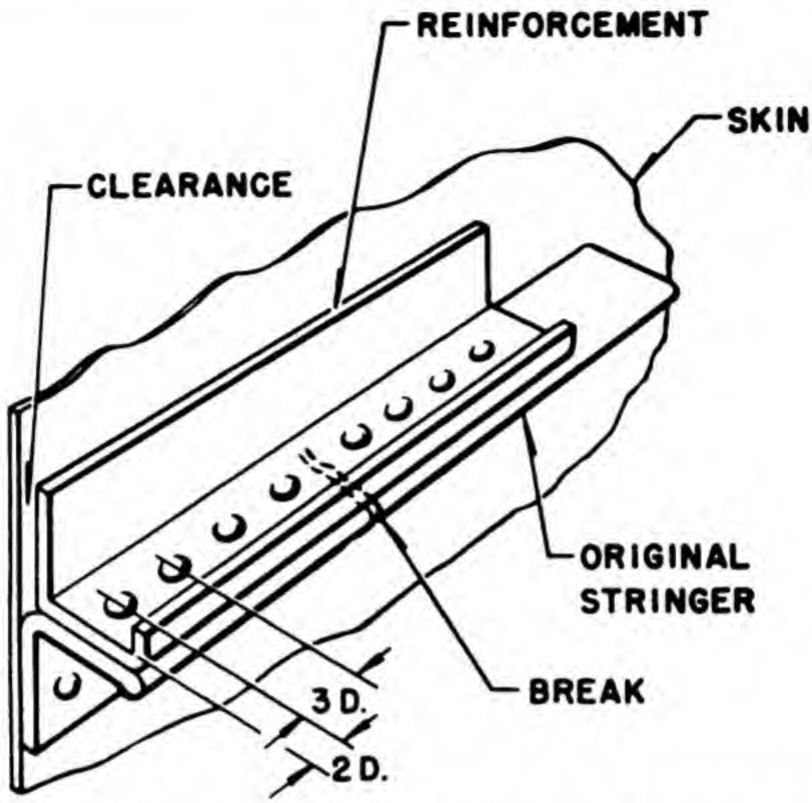


Figure 131.—Alternate method for repairing bulb extrusion angle.

SPLICES

A FILLER SPLICE is a short section of the same shape as the original stringer. It is used to fill the space left when you take out a damaged length of stringer. A filler splice should never be longer than 12 inches.

When you remove the damaged stringer section, it is best to cut out the end in the center of two rivets so that the rivet continuity can be maintained in the repair. Cut the damaged part square and file the ends smooth.

Cut out the filler but make it 1/32 inch SHORTER in length than the length of the damaged section. This will allow a clearance of 1/64 inch between each end of the replacement and the original stringer, thus elimi-

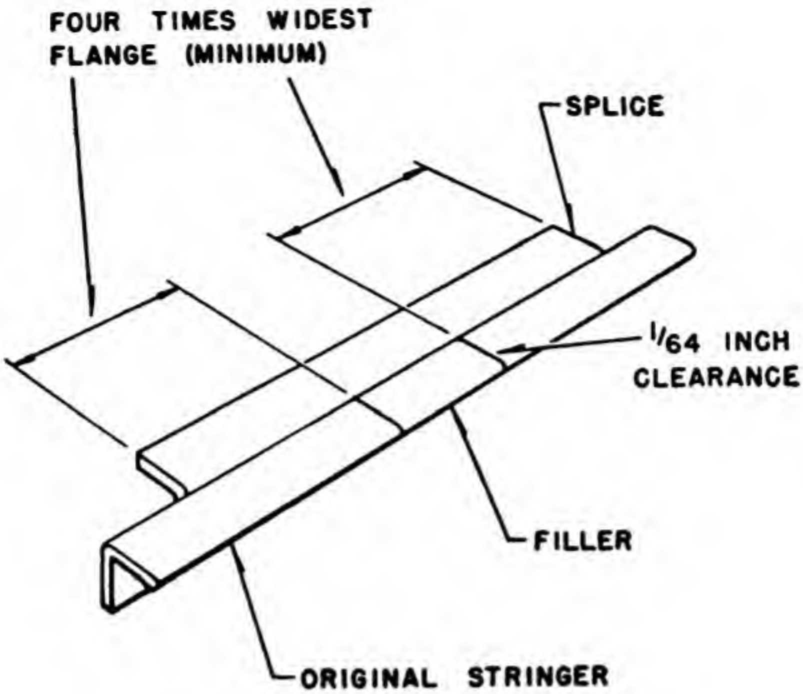
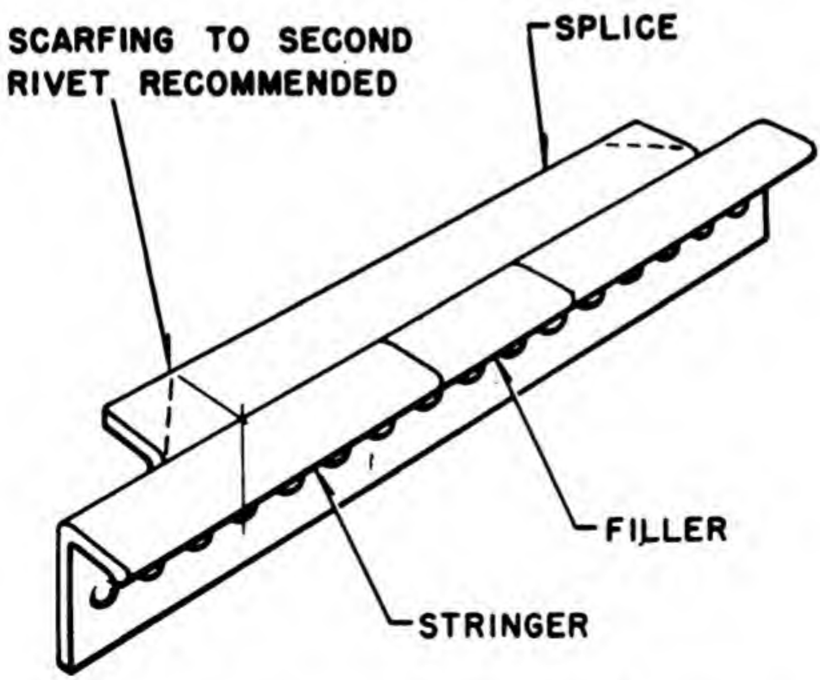


Figure 132.—Filler splice.

nating any possibility of stress developing from contact between the two parts. Figure 132 shows this clearance.



DAMAGE LESS THAN 12" INCHES

Figure 133.—Bulb angle repair using filler and reinforcement splices.

The REINFORCEMENT SPLICE to be used with the filler splice, should be long enough to extend at least four times the width of the stringer on each side of the damaged area. Figure 133 shows the completed assembly with filler and reinforcement splices in place.

An important consideration in repairing a cracked or damaged stringer is the number of rivets necessary to reinforce the angle on each side of the crack. Since stringers and reinforced angles are extremely varied as to their shapes and sizes, it is difficult to set down any general rules.

The materials of which stringers are made all have specific allowable loads which they will carry. For most types of repairs and for most stringer materials the figure of 43,600 pounds per square inch (psi) is considered to represent the allowable stress.

Based on this figure, here is a table which indicates the approximate number of rivets which you will need on each side of the damaged area.

TABLE XI

Required Rivets for Stringers

Thinnest sheet 24ST gage material	Rivets 1/8"		Rivets 5/32"		Rivets 3/16"	
	A17ST	17ST	A17ST	17ST	A17ST	17ST
0.020	3.9	3.9	....	....	....	....
.025	3.9	3.9	....	....	....	....
.032	4.5	3.9	3.1	3.1	....	....
.040	5.7	4.7	3.6	3.1	2.6	2.6
.051	7.3	6.1	4.6	3.9	3.2	2.7
.064	9.0	7.6	4.8	4.0	3.3	2.8

Figures under "rivet" columns represent the number of rivets required per inch of damaged cross sectional width.

Here's an example of how to use this table. Figure 134 shows that a crack has occurred in the channel section. This section is 3 inches across and ¾ inch up on

each side, so that makes a total crack length of 4½ inches. The metal is .032 24ST rib and the rivets you are going to use are ⅛ inch 17ST. O.K. Take a look at the chart and with that material and using those rivets, you will need 3.9 rivets per inch of cracked damage.

Multiply 3.9 by 4½ inches and you get approximately 18. That is the number of rivets you will need on each side of the damage.

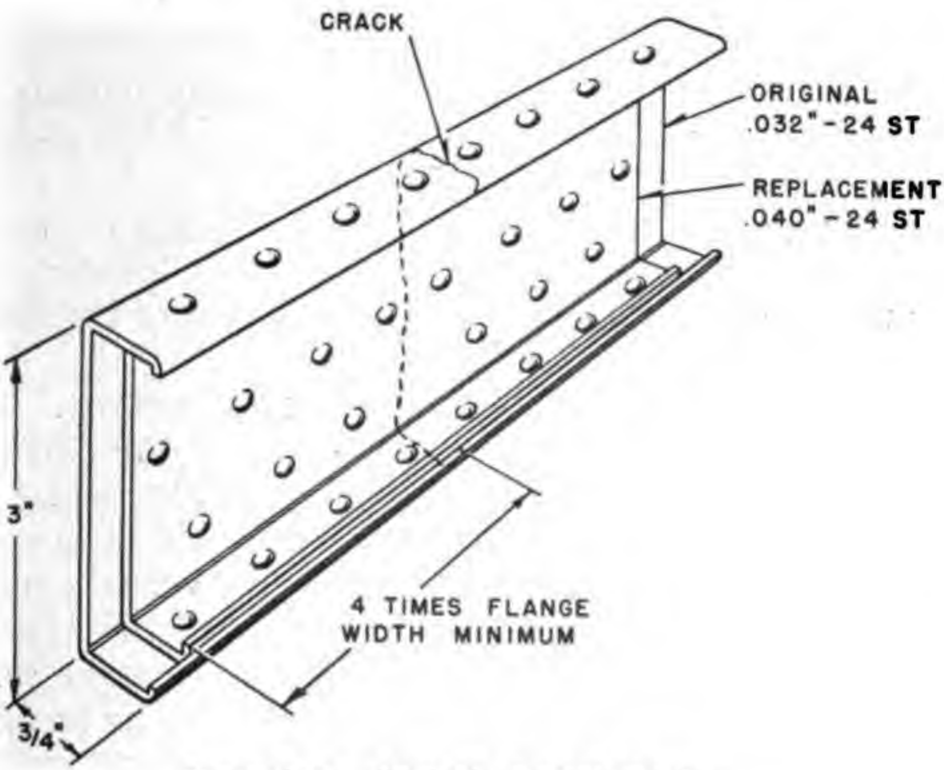


Figure 134.—Typical channel repair.

If possible, use manufactured extruded stock for splices. If no manufactured stock is available you can make suitable replacement from sheet stock at least one gage thicker and formed to the same cross sectional area as the original.

Locate and drill rivet holes in the reinforcement plate according to the standard riveting rules. The edge distance measured from the center of the rivet to the edge of the sheet should be two times the rivet diameter.

The spacing between rivets should equal three to four times the rivet diameter. The rivet size should be the same as that of the rivets installed at the factory. It may be necessary to insert ADDITIONAL rivets at the ends of the stringer and at the ends of the filler block.

After you have drilled the rivet holes through the reinforcement plate, clamp the filler plate to it and drill matching holes through the filler plate. If the skin of the airplane is curved to any extent and if the drilling has to be done on the airplane itself, you may find it necessary to use an angle or extension drill to make the holes.

If possible, stagger the rivets, especially if there are two or more rows of rivets on one leg of the stringer you are repairing.

Suppose the damaged area of the stringer is LONGER than 12 inches. Then, as you have just learned, you cannot use a filler splice because the limit of its usefulness is one foot.

Instead, you will use an INSERTION SPLICE. This type of repair is used when the length of the damaged area is longer than 12 inches. It includes using the filler of the correct length which is fastened to the original stringer by INDIVIDUAL REINFORCEMENT SPLICES at each end. Figure 135 shows where this type of repair is logical. If it is necessary to splice MORE THAN ONE stringer, be sure to stagger the splices as in figure 135 so that no two of them fall at the same station.

SPLICING FORMED STRINGERS

If you have a formed stringer to repair, it is sometimes possible to use a manufactured extruded angle for reinforcement or filler, IF it is altered to fit the stringer being repaired. In most cases, however, it is much easier to form a reinforcement splice from sheet metal by using a brake. By forming a reinforcement splice, it is possible for you to get the same radii as that of the original stringer.

Remember to use, for filler material, metal of the same gage as the part being repaired. The bend radius of the material being shaped must be kept within the allowance limit, otherwise it will crack or be weakened.

Once you have formed the reinforcement splice TO

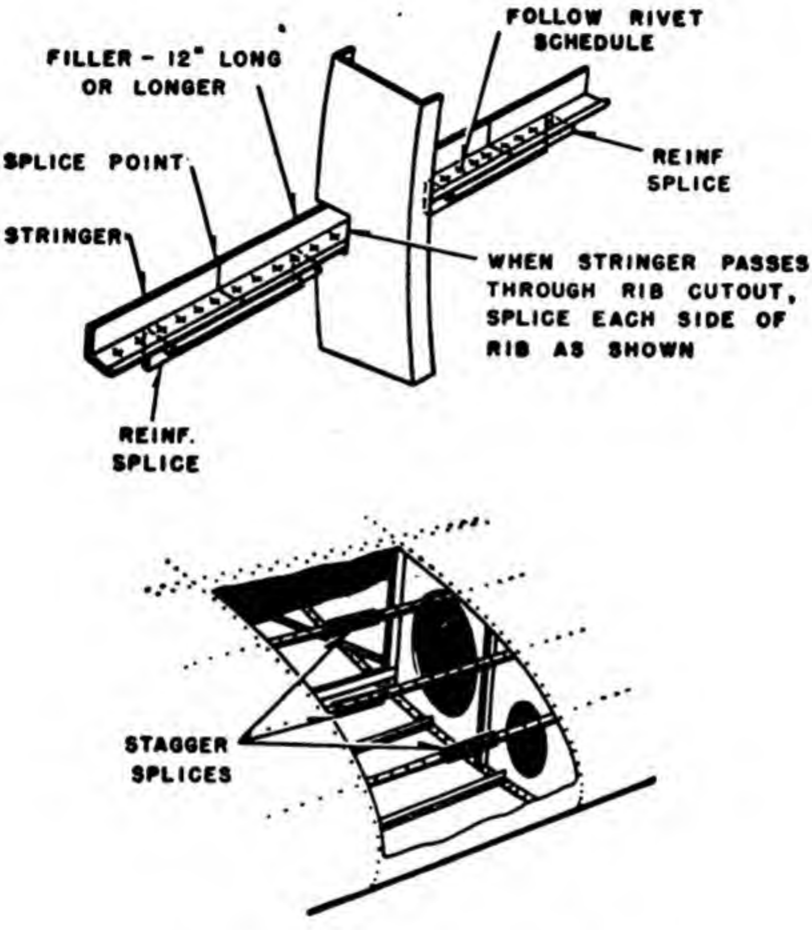


Figure 135.—An insertion splice.

EXACTLY THE SAME SHAPE as the original, follow the same procedure as that for repairing an extruded angle stringer.

Figures 136, 137, and 138, illustrate a number of typical repairs to FORMED angle stringers. Figure 139 shows typical repairs to EXTRUDED angle stringers.

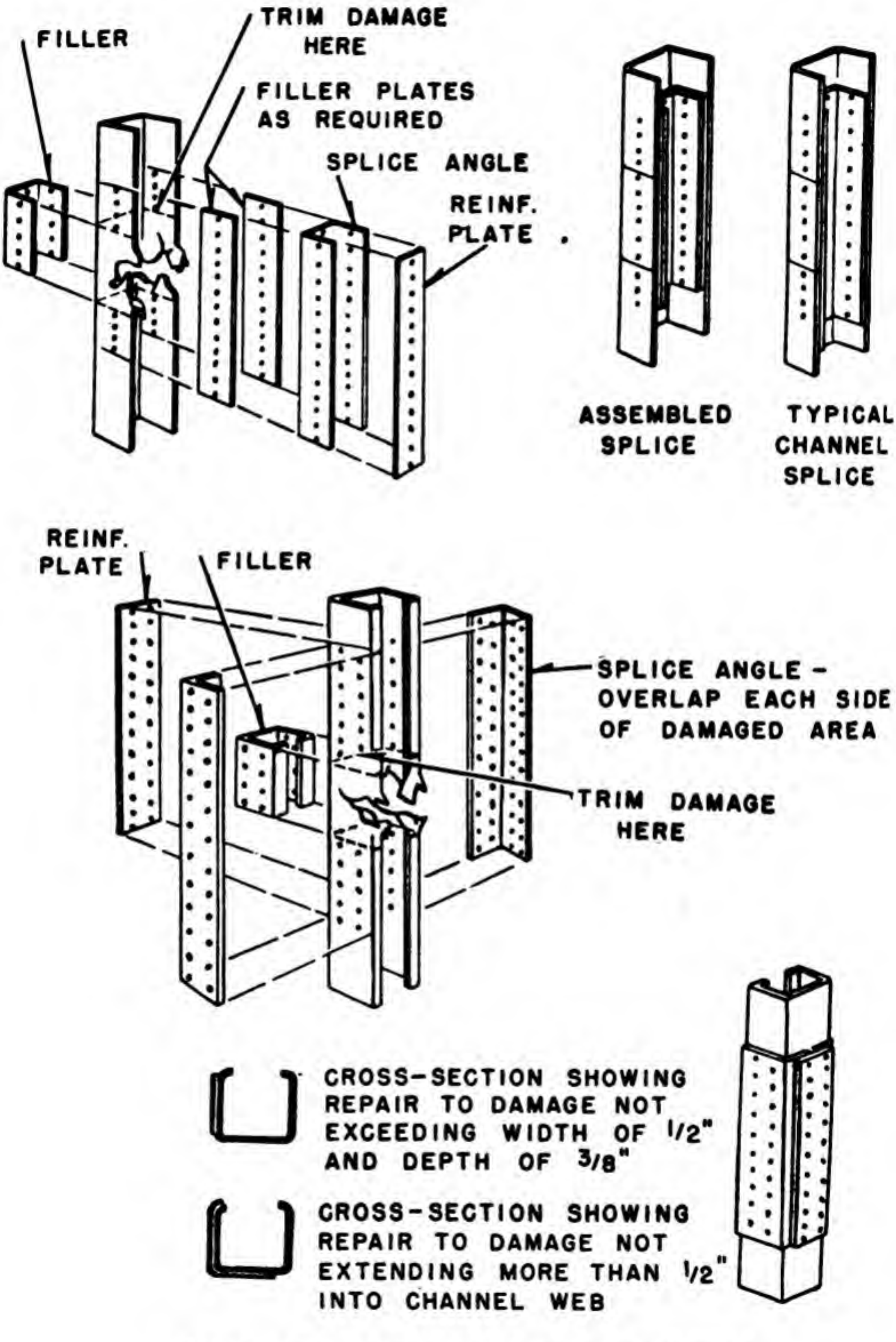


Figure 136.—Splicing damaged channel webs.

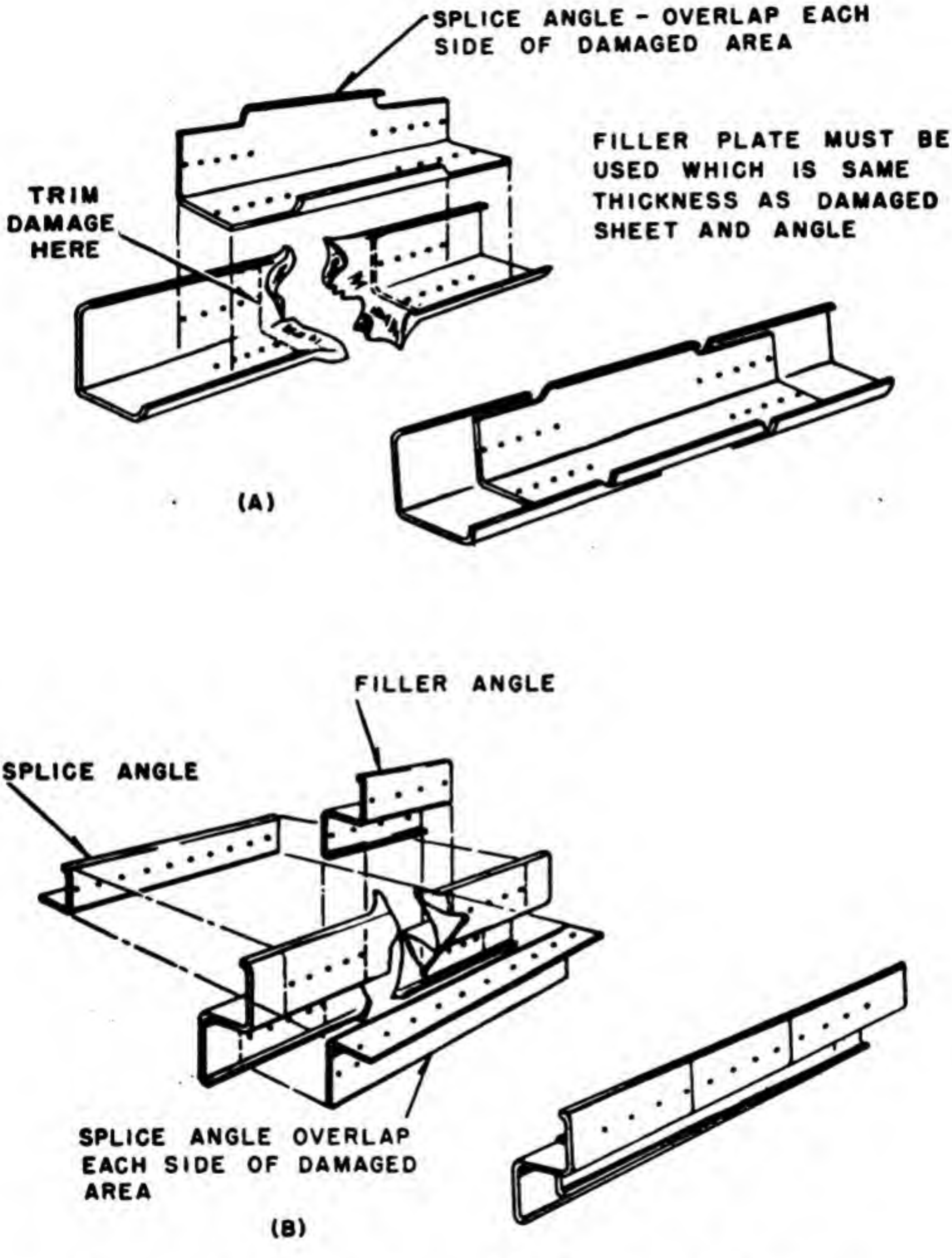


Figure 137.—Splicing damaged bulb angle and Z stringers.

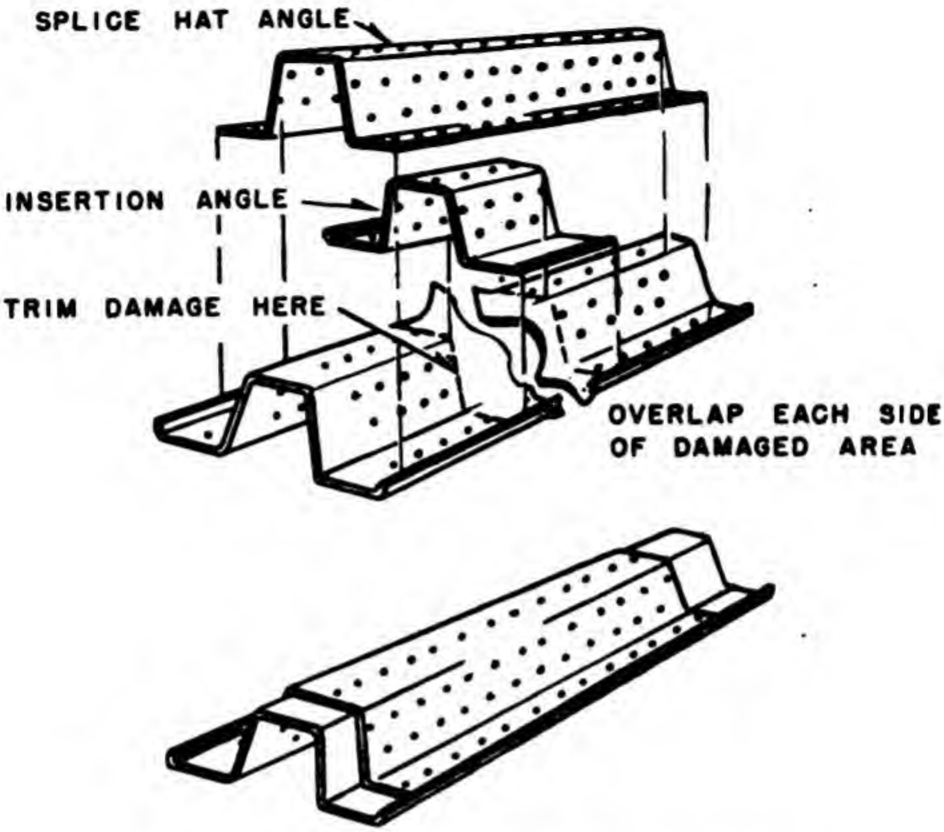


Figure 138.—Splicing a damaged hat angle.

Figure 139.—Typical repairs to extruded angles.

REPAIRING SPARS, RIBS, AND BULKHEADS

Your work in repairing wing spars, ribs, and bulkheads is limited to RIVETING REINFORCING PLATES AND MAKING SPLICES to the structures.

General repair procedure is about the same for all of these members.

Cut out the jagged edges of the damaged section, remove any dents and round off the sharp edges with a file. You may stop the spread of cracks by drilling small holes at either end of the crack.

Remove all of the rivets from the damaged area

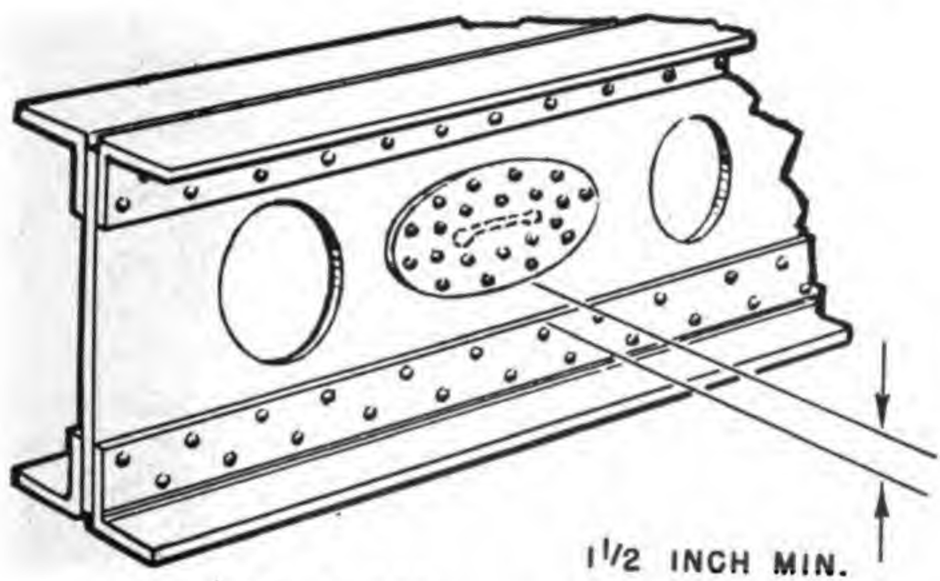


Figure 140.—Patching a crack in a spar web.

WITHOUT enlarging the holes. Then cast your eye over the surrounding area and whenever you spot any other damaged or loose rivets replace them. Adhere to the rivet patterns in the original structure except when closer spacing and edge distance is necessary. Always use the same size rivets as those which were in the part originally. If you find that one or more of the rivet holes are oversize, then use the next larger diameter of rivet.

The repair material must be of the same alloy as the original and the same gage or one gage thicker.

SPARS

Spars are members which run the entire length of an airplane wing. Since their purpose is to carry the BENDING loads imposed on the wing, all repairs must be made so that there will be no loss of strength.

CRACKS IN SPAR WEBS may be repaired in the same manner as those in any stressed skin section. Drill a small hole at each end of the crack and rivet a patch over it, like that in figure 140.

HOLES in webs most likely will be made by bullet or cannon fire. Although it is impossible to outline all

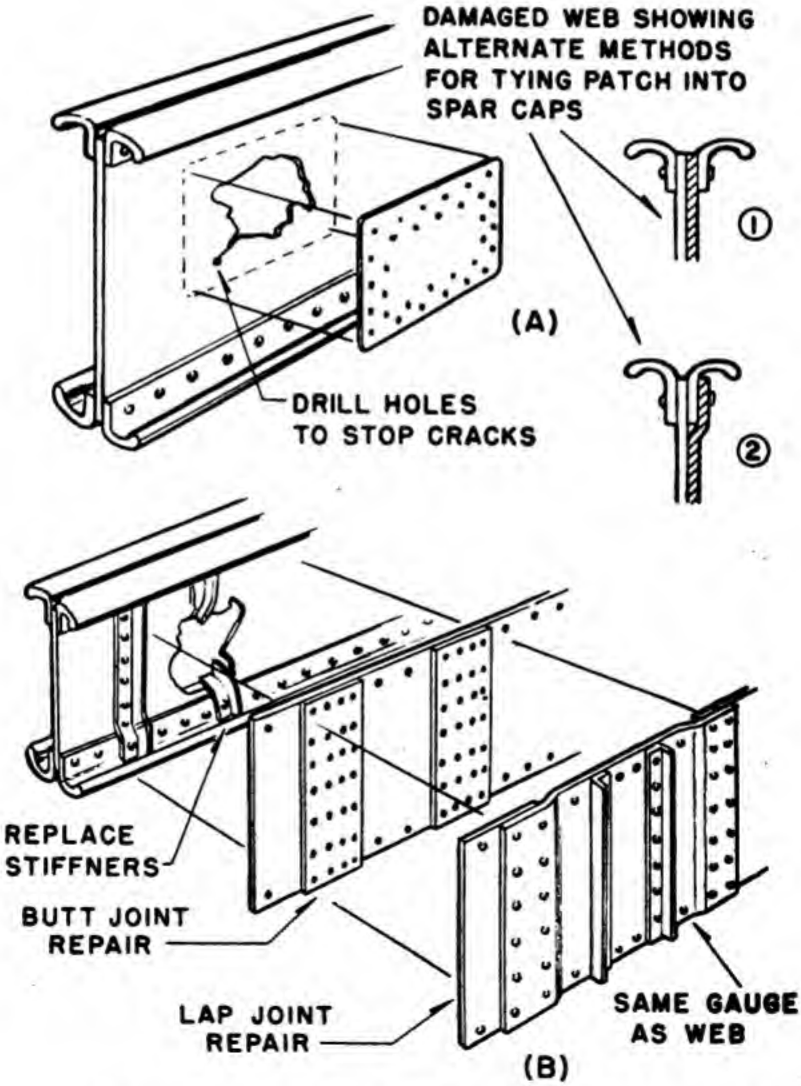


Figure 141.—Repairing holes in spar webs.

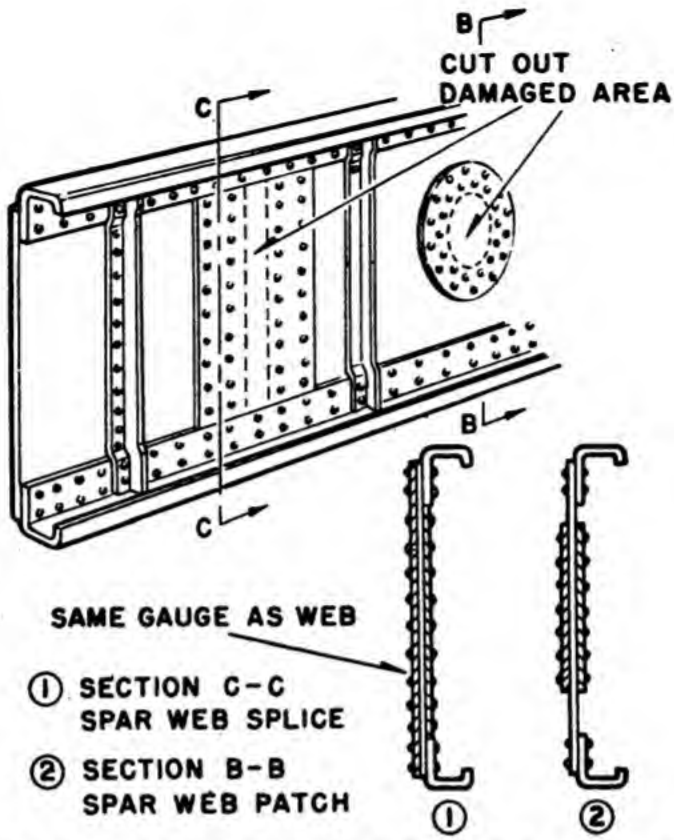


Figure 142.—Two methods for repairing a damaged web.

of the kinds of damage which might occur, the repair procedures which follow will apply in most cases. Figure 141 shows some typical repairs to holes in spar web members that will help you repair any similar damage.

If the damage occurs near a lightening hole, cover the hole by placing the patch on the side OPPOSITE the hole's flange.

Figure 142 illustrates two repair methods. If damage to the web extends almost into the flange, cut away the damaged area and use splices on both sides of the web shown in the cross section C-C at top left in the drawing.

If damage to the web is small, right, in the top drawing, you may simply use a patch.

Figure 143 shows a repair to a spar where the damaged section is removed but where a filler is not used except at the top and bottom of the flange, where the spar is attached to the skin. These two insertion fillers

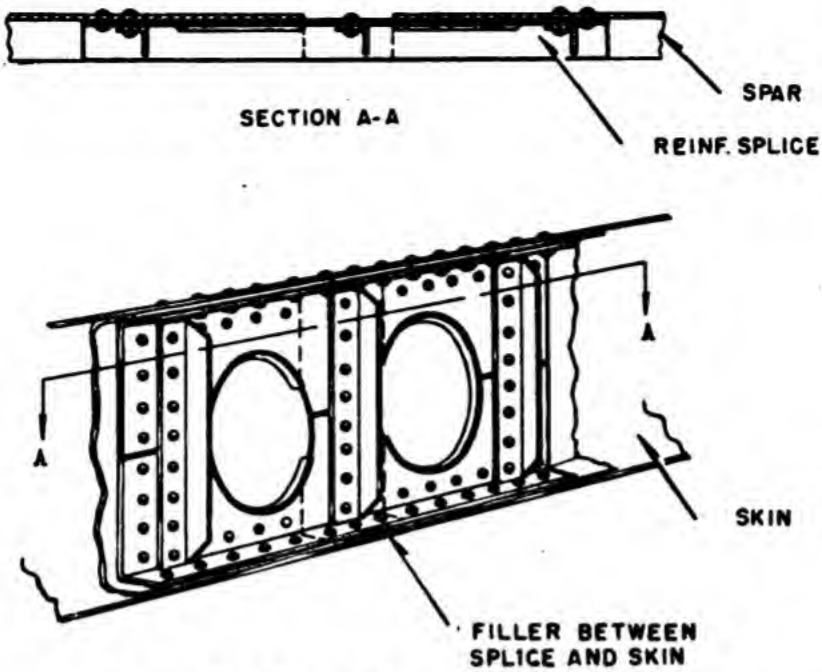


Figure 143.—Using two insertion fillers.

at the top and bottom of the flange are needed so that the rivet pattern can be followed. Notice that a split reinforcing splice is used. After you have riveted this splice to the spar, stiffen it by riveting an angle to it.

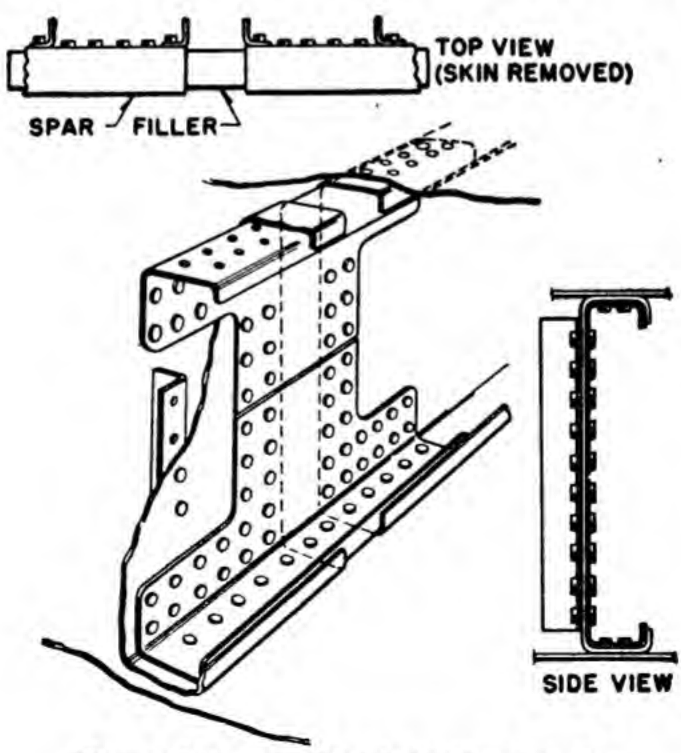


Figure 144.—Split reinforcing sleeve.

When spar FLANGES are damaged, the damage usually extends into the web and you will have to repair both parts. If the spar is of the channel type, flange and web repairs must be made together. The illustrations show some typical examples.

Figure 144 illustrates a typical repair to a channel

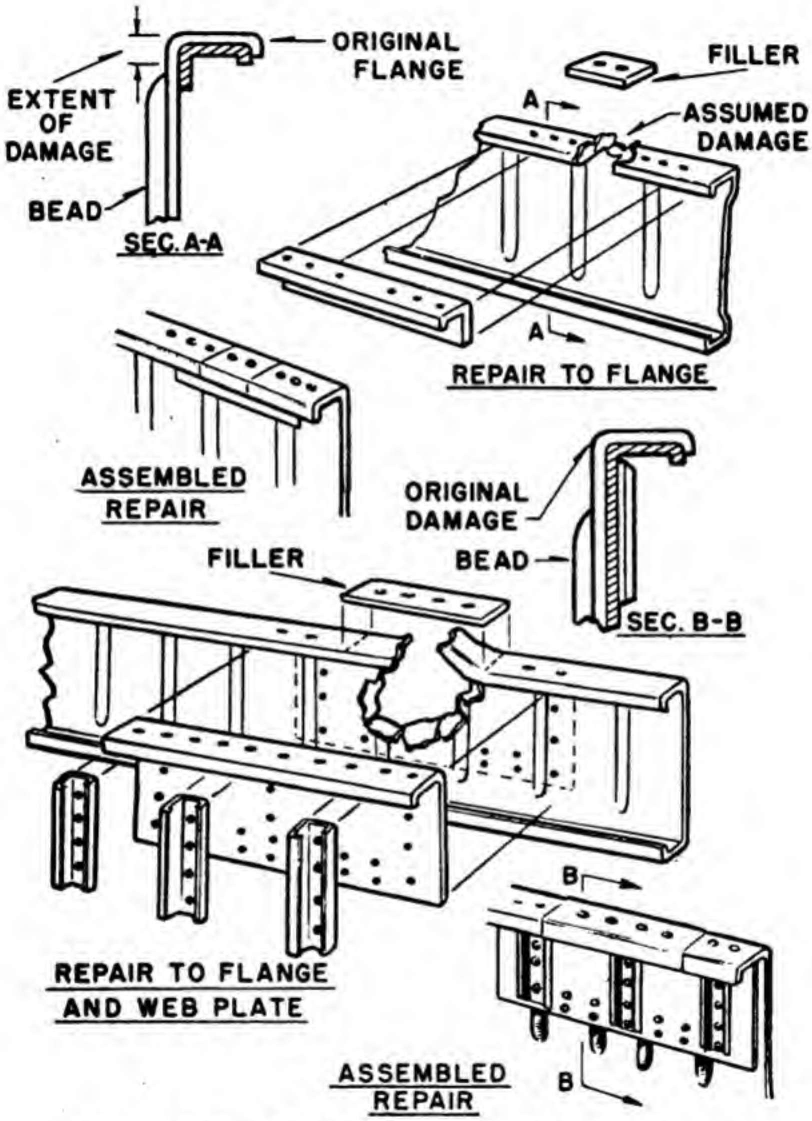


Figure 145.—Repairing spar with torn flange.

type spar using the split reinforcing splice and a filler. The splice must be split because a single-piece splice could not be inserted into the channel. Figure 145 shows several ways to repair a spar which has a tear in the flange.

REPAIRING RIBS

Wing ribs, in addition to maintaining the shape and rigidity of the wing, are designed to pass along wing loads from the skin to the spars. They are required to resist COMPRESSION loads as well as SHEAR loads.

Ribs are most generally of three types. (1) The trussed rib type. (2) The type with bent-up sheet flanges and with flange holes in the web. (3) The type with solid web ribs with extruded angle or channel stiffening flanges. Figure 146 illustrates these three types of ribs for your convenience.

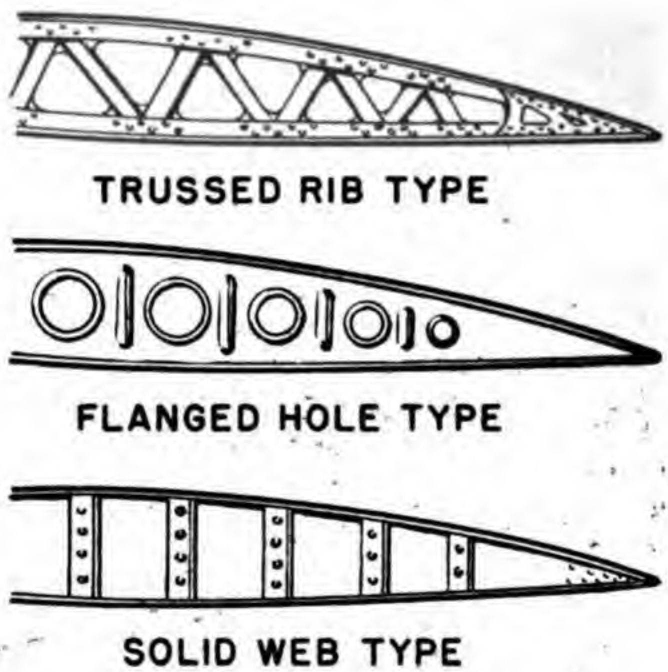


Figure 146.—Wing ribs.

Figure 147 shows typical repairs to damaged capstrips. These capstrips are found in the trussed rib type.

In figure 148 (*A*), you see a typical repair of buckled rib webs and in figure 148 (*B*), a typical rib splice.

In figure 149, you see a typical rib flange repair where the flange is riveted to the skin. Figure 150 shows a repair of broken rib beads.

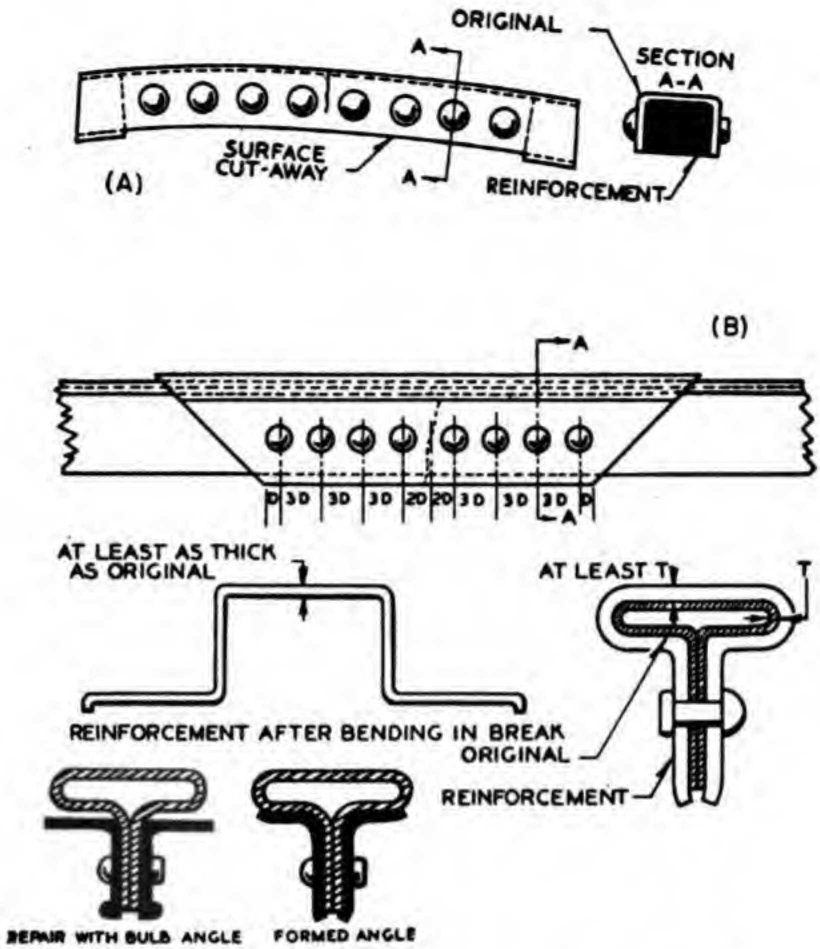


Figure 147.—Repairing damaged capstrips.

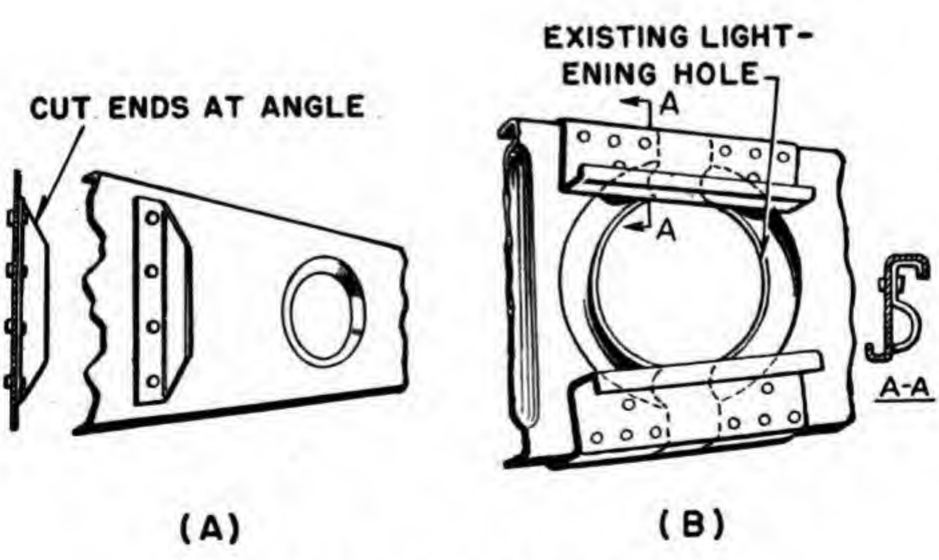


Figure 148.—Repairing wing rib webs.

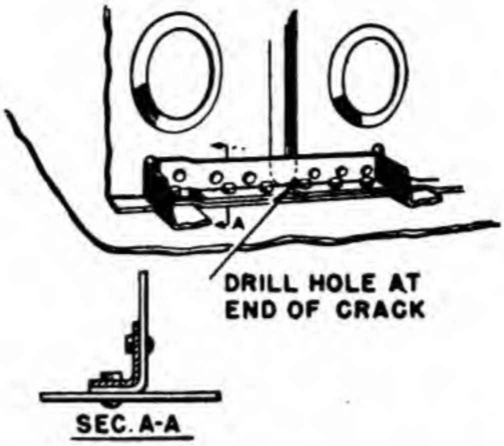


Figure 149.—Repair of flange riveted to skin.

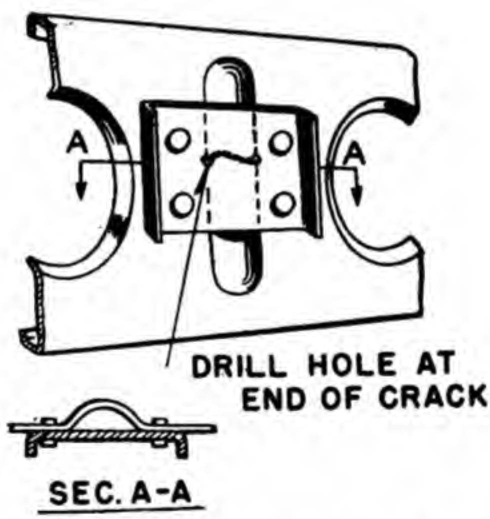


Figure 150.—Repair of broken rib beads.

A typical repair of a cracked rib flange where the flange IS NOT riveted to the skin, is shown in figure 151. Figure 152 shows a typical reinforcement to a cracked lightening hole.

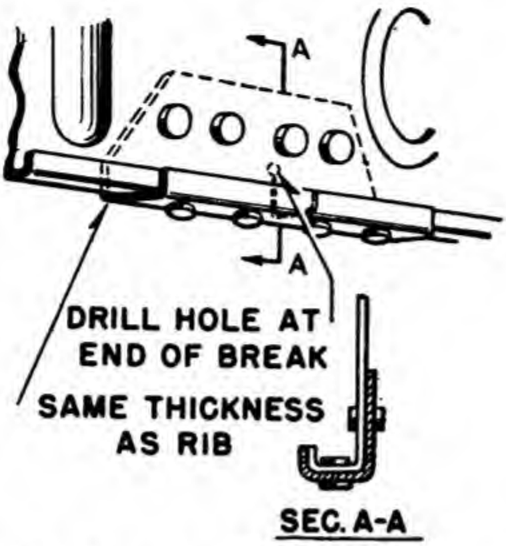


Figure 151.—Repair of flange not riveted to skin.

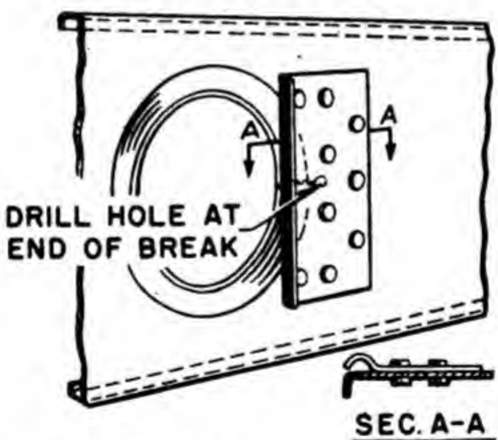


Figure 152.—Repair of cracked lightening hole.

A center section of a wing rib may be spliced as shown in figure 153 (*A*). A typical trailing edge rib splice is shown in figure 153 (*B*).

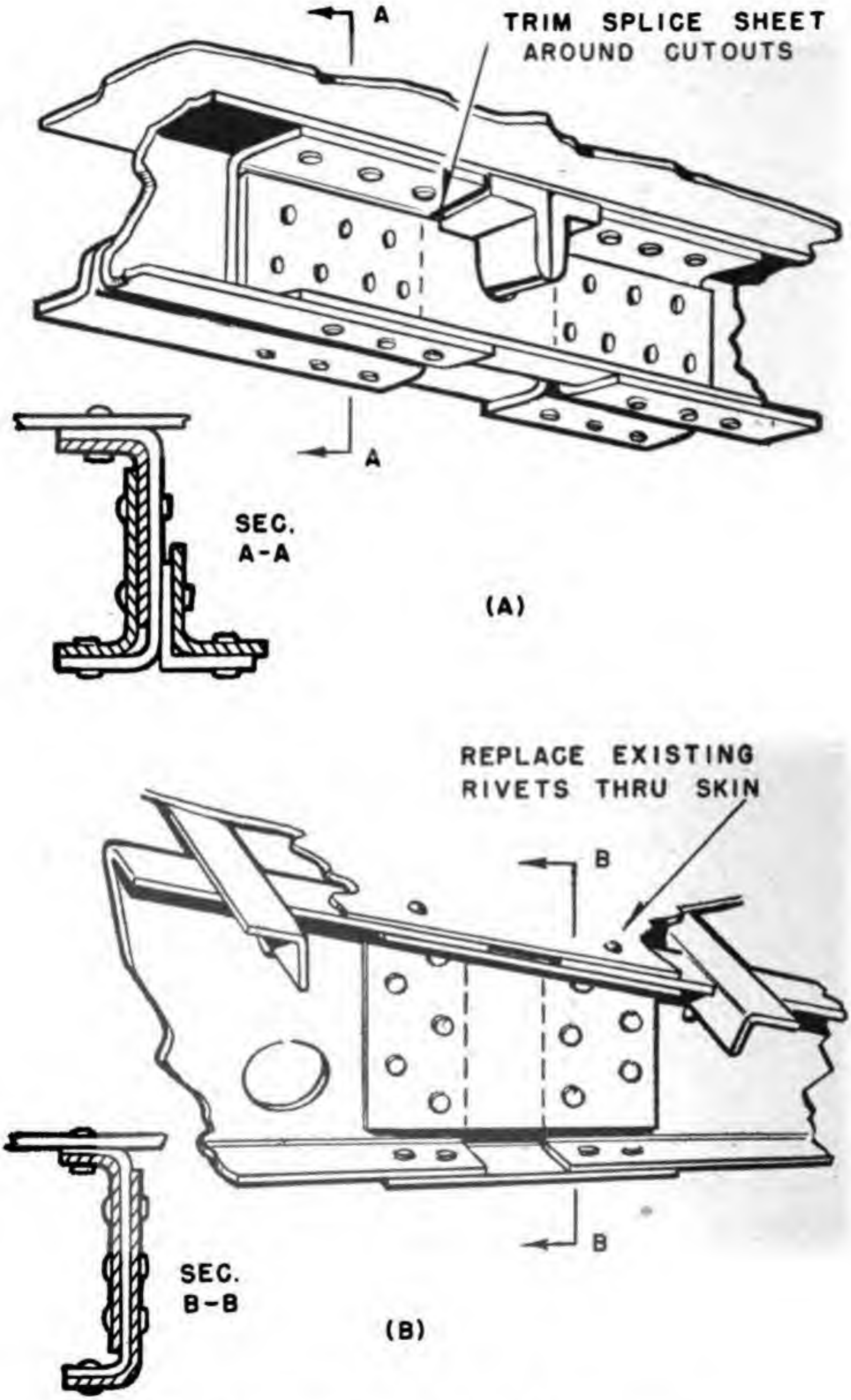


Figure 153.—Splicing of wing rib sections.

Figure 154 is a picture of the repair to a wing flap rib.

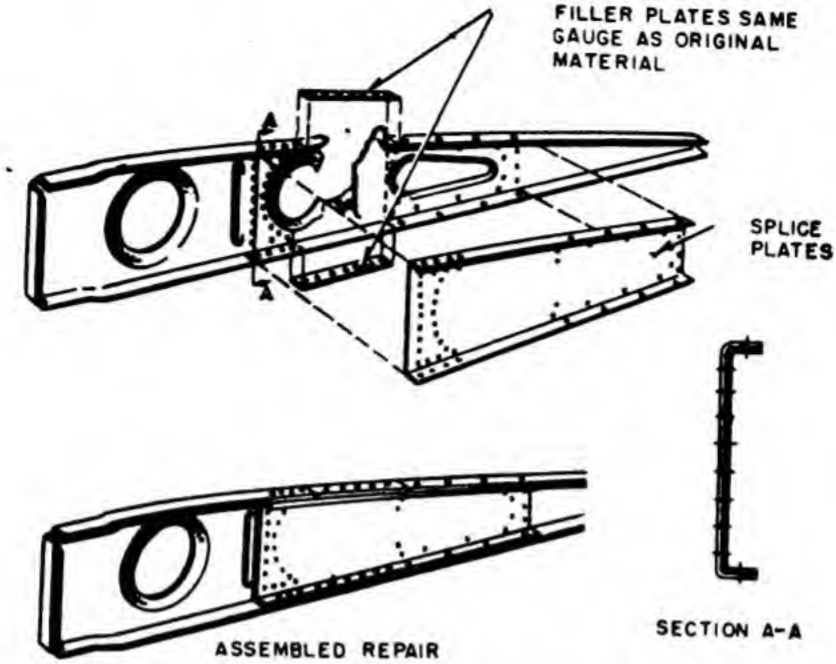


Figure 154.—Typical repair of wing flap rib.

Repairs to wing leading edge ribs are shown in figures 155, 156, and 157.

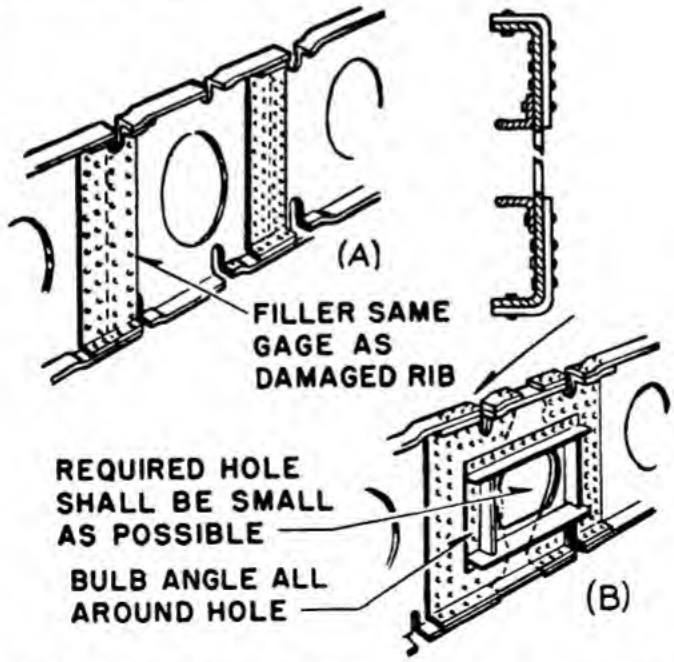


**Figure 155.—(A) Splice for damage greater than 5 inches.
(B) Field repair when hole is needed.**

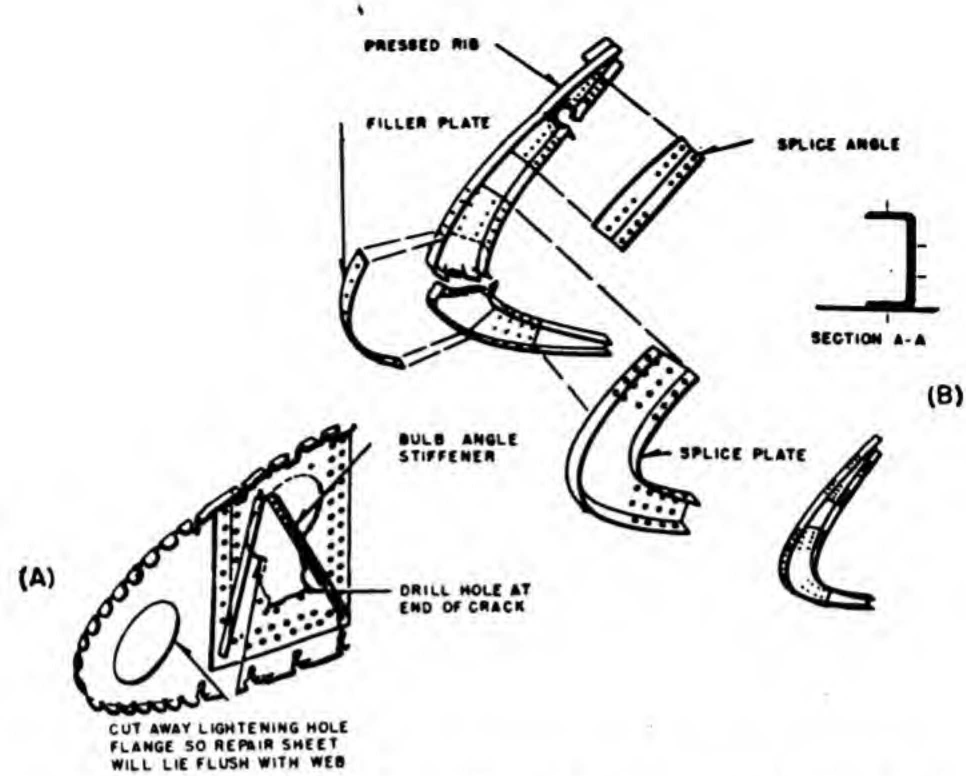


Figure 156.—(A) Repair of partial damage. (B) Repair to leading edge rib.

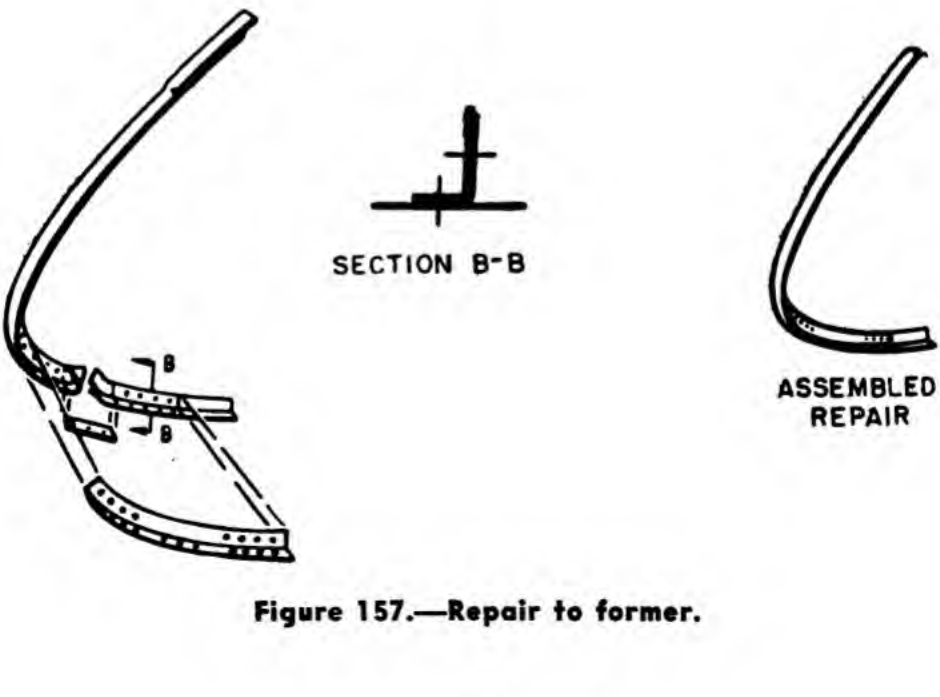


Figure 157.—Repair to former.

BULKHEADS

A bulkhead, in the broad sense of the word, includes any partition. In this sense, reinforcing rings, former rings and belt frames are BULKHEADS. All members of an airplane which separate compartment and fuselage stations are designed to carry CONCENTRATED loads.

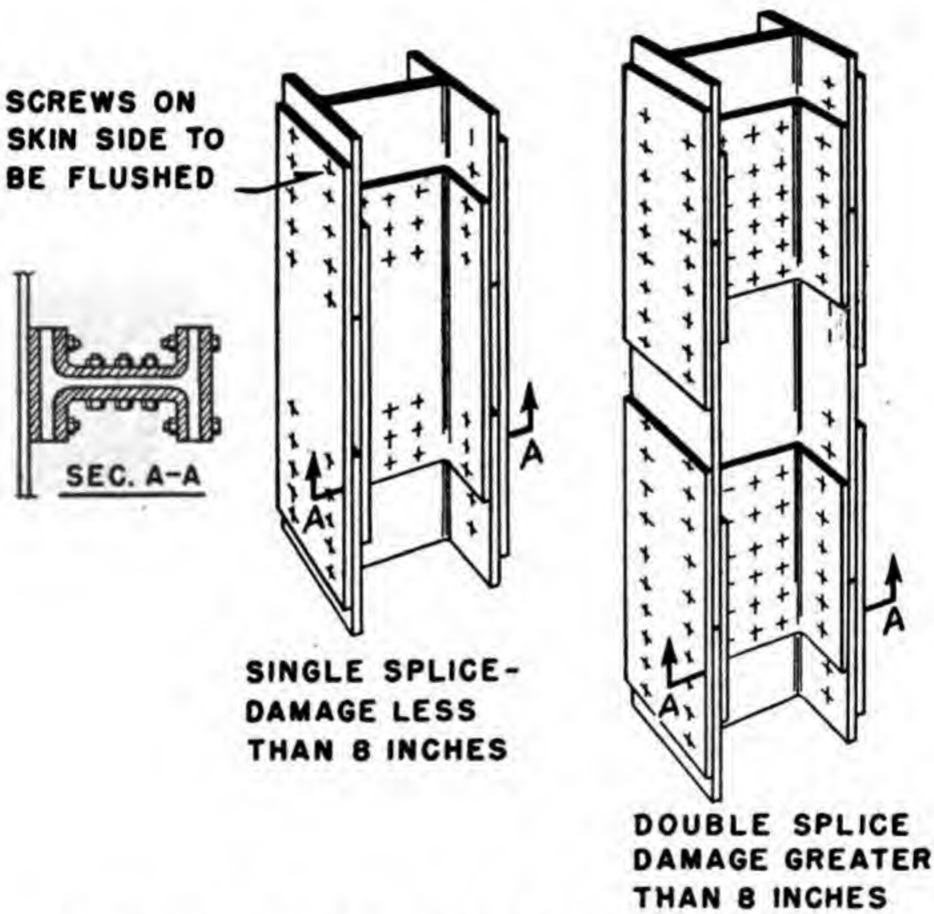


Figure 158.—Total repairs for frames .091 in thickness.

Therefore you must use your head when making repairs to these members.

The accompanying illustrations show the various methods for repairing damage to bulkheads.

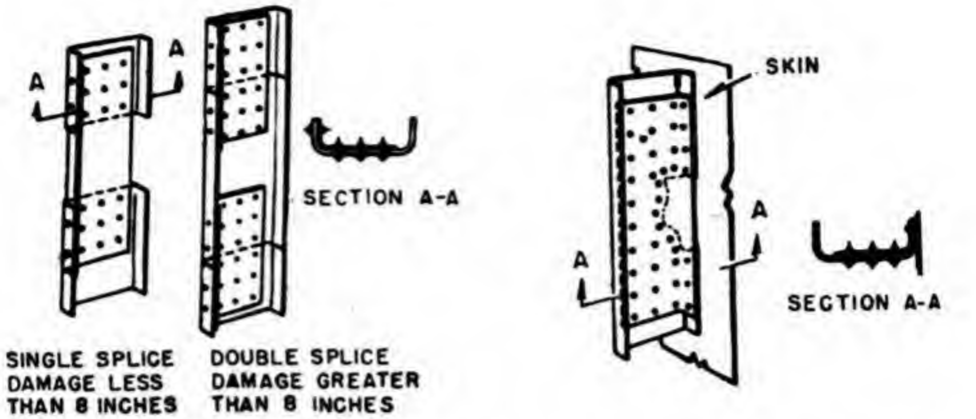


Figure 159.—(Left) Total repairs for frames .040 inch, .051 inch, and .064 inch in thickness. (Right) Partial repair for all frames.

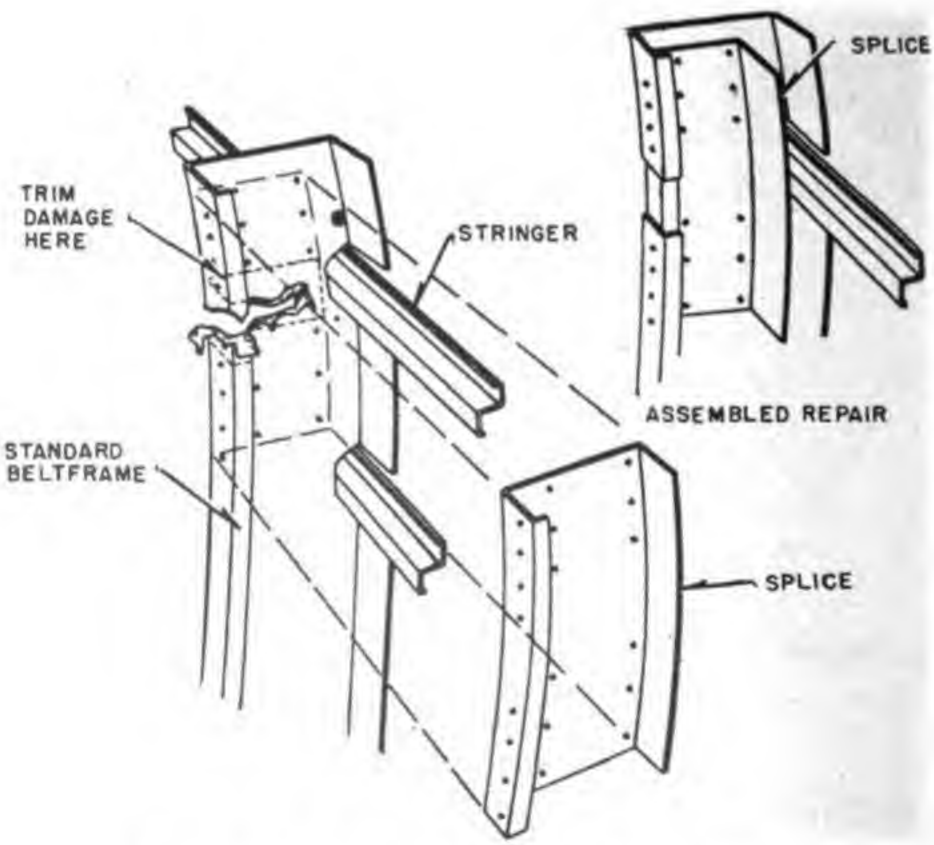


Figure 160.—Repair for standard belt frame.

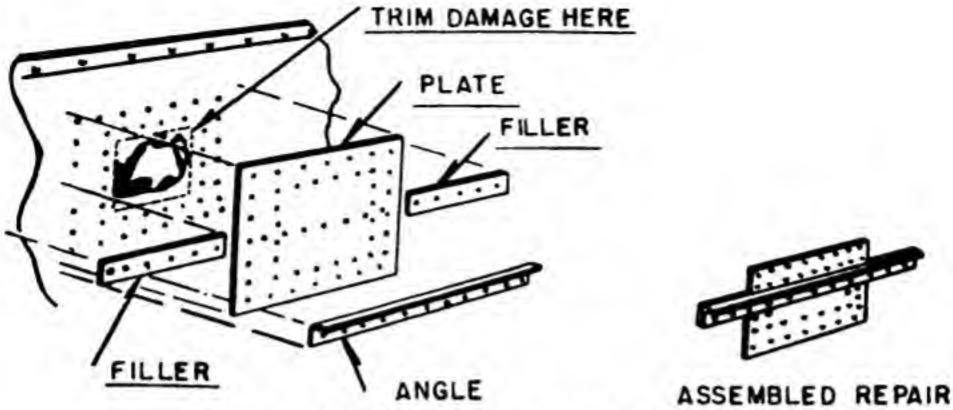


Figure 161.—Web repair on bulkhead.

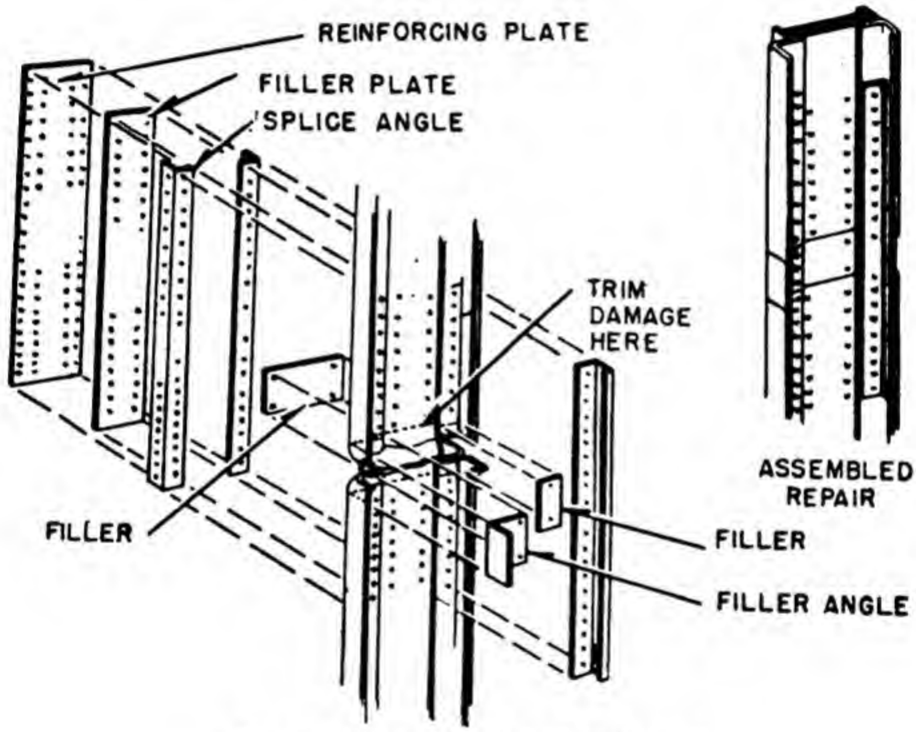


Figure 162.—Repair of stringer.

TRAILING EDGE GEAR

A trailing edge is the rearmost edge of an airfoil; that is, a wing, aileron, rudder, elevator or stabilizer. It is generally a metal strip which forms the shape of the edge by tying the ends of a rib section together and joining the upper and lower skins, as in figure 198. Trailing edges are not structural members but you

should consider them as being lightly stressed in all cases.

KINDS OF TRAILING EDGE REPAIR

Trailing edges may be covered with either metal or fabric, depending on the relative importance of the rigidity and weight required by the airfoil. Most control surfaces are covered with fabric in order to reduce their weight and thus make operation easier and the controls more accessible, and reduce vibration of the airfoil. Metal covered control surfaces have more flutter or vibration, which makes the operation of the controls more difficult.

The ROD type of trailing edge is generally used on small fabric covered control surfaces. Damaged sections of rod must be replaced FROM WING RIB TO WING RIB and must be fastened in place with metal clips.

TUBING is used in place of a rod for a trailing edge in larger fabric covered control surfaces. This edge probably can best be repaired by inserting a solid reinforcement splice. You would then rivet the original tubing to it. In order to insert the splice, you can either spread the tubing at the break or cut away part of its surface. Figure 163 shows a reinforcement splice inserted in a cracked tubing trailing edge.

A small airplane with correspondingly small wing and control surfaces might employ a SOLID BAR like that in figure 163, to give the trailing edge its required stiffness. These bars are used in airfoils which are covered with metal, rather than fabric. You can repair them by simply fastening a reinforcement splice or a patch of sheet stock over the break, as shown in the illustration.

An OVERLAPPED SKIN trailing edge is found in some metal covered airfoils. In such cases the upper and lower skin surfaces are overlapped enough to permit them to be riveted together. This type of trailing edge may be repaired by using a reinforcement patch of

sheet stock which is joggled to conform to the contour of the overlapping skins.

The CHANNEL type is probably one of the most commonly used trailing edges. You'll find it in both metal and fabric covered airfoils. Repairs for it will be discussed later because they involve a number of typical operations.

The damage to trailing edges of wings, control surfaces, or flaps may be limited to one point or may extend over an entire length between two or more rib sections. The damage can be caused by gun fire, col-

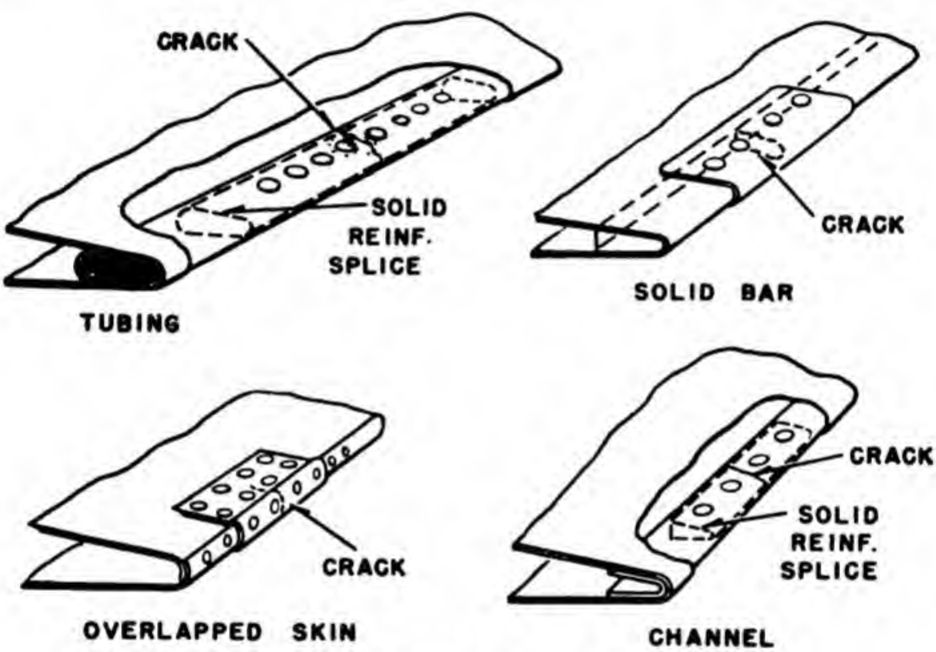


Figure 163.—Repairs of typical trailing edges.

lision, ground looping, or even careless handling on the the ground. The result is buckling, cracking or holes. You must remember that trailing edges are particularly subject to corrosion although it may not always be apparent. Moisture tends to be trapped in the trailing edge part of the wing when the drainage holes become clogged.

THE REINFORCEMENT SPLICE OR PATCH

If the damage is simply a CRACK or BREAK in the

trailing edge, you can restore it to its original strength with a reinforcement splice or patch. The shape and kind of reinforcement will be determined by whether the airfoil is covered by metal or fabric. When you are to make the reinforcement from an extruded shape, choose one which is the same shape and temper as the original in order to restore the initial strength. For trailing edges with a small radius, you can make the splice most easily out of solid material, such as aluminum alloy, micarta, or bakelite.

In cases where you must make the reinforcement from sheet stock, choose stock which is one gage heavier than the original member and which is of the same temper. In this case you must form the reinforcement to fit the original.

NEW SECTIONS

Sometimes damage to a trailing edge extends over

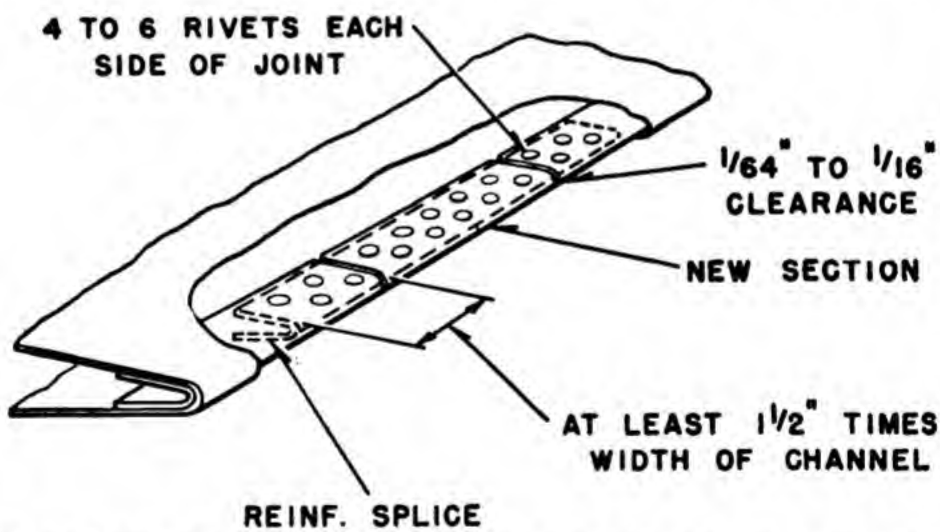


Figure 164.—Repair of trailing edge by inserting a new section.

such an area that you must remove and replace a whole section of it. In this case, the new section must duplicate the original in size, shape and temper. It may be an extruded shape or it may be formed from sheet stock, depending upon the available material. Figure 164 shows a new section inserted in a trailing edge.

Cut away the damaged area if it is badly crushed or distorted. If it is only cracked, straighten the damaged part and insert a reinforcing splice.

If the damage requires that you insert a new section, determine the length of the section to be replaced. Cut a new section of the same material and gage as the original from either an extruded shape or sheet stock. When you figure the length of the new section, allow a CLEARANCE of $\frac{1}{64}$ to $\frac{1}{6}$ inch between the ends of the new section and the original trailing edge.

If the new section is to be formed from sheet stock, form it in a cornice brake to the same shape as the original.

Burr all edges and slightly round the corners on both the new section and the exposed ends of the original.

Now cut a reinforcement splice of the same metal and one gage heavier than the original. Figure the length of the splice according to the width of the trailing edge section. It should extend at least $1\frac{1}{2}$ times the width of the trailing edge section on EACH SIDE of the break or joint.

Because this repair is on a non-structural part, the rivets need not be spaced so closely. A distance of about eight rivet diameters between rivets is sufficient.

Mark the rivet location on the reinforcement splice. If necessary, the rivets may be STAGGERED in order to make it possible to head them.

Now clamp the new section and the reinforcement splice together and drill the rivet holes.

Next fasten the pieces temporarily with sheet fasteners and then rivet them together.

In figure 165, you see several other methods by which trailing edges may be repaired. At top you see filler blocks used with a reinforcement splice which is wrapped around the trailing edge. Immediately below, a filler block of Dural is used and the reinforcement splice around the trailing edge is omitted. The next drawing shows a one piece reinforcing splice used when the damage extends less than 6 inches. The bottom

drawing shows the reinforcing splice cut into two pieces. This type is used when the damage is greater than 6 inches.

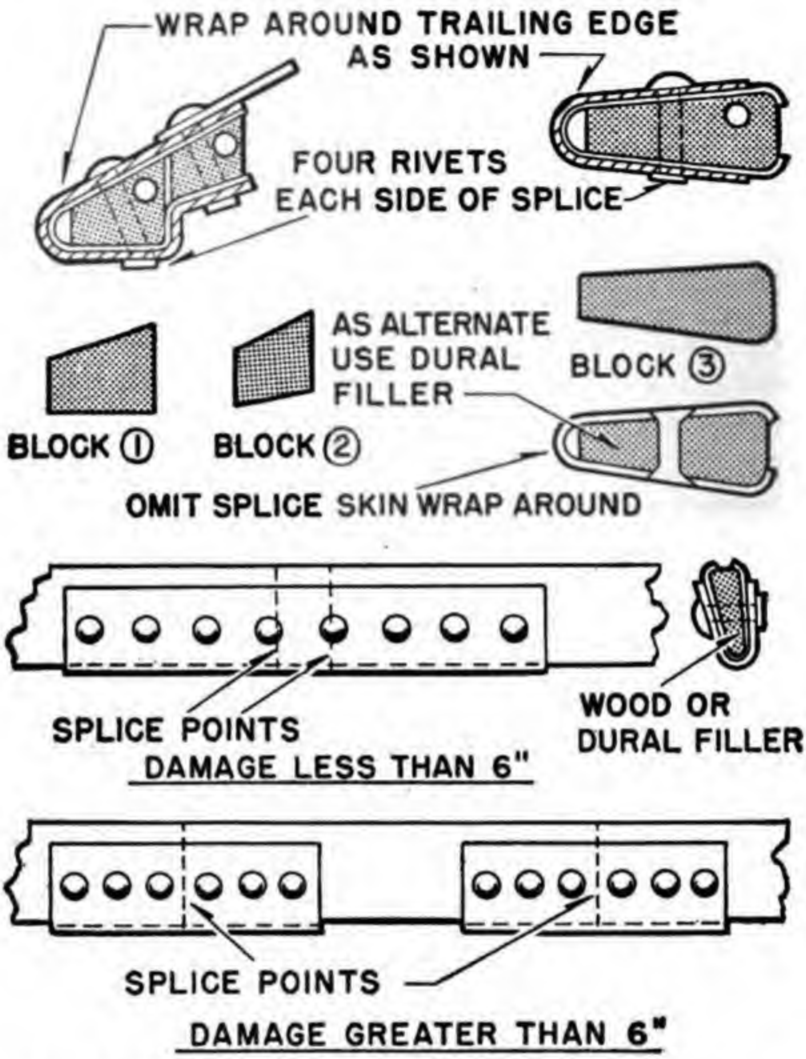


Figure 165.—Other types of trailing edge repairs.

SKIN REPLACEMENT

The skin of a modern high-powered airplane is AN IMPORTANT STRUCTURAL MEMBER because it gives shape to the different parts of the airplane and aids the reinforcing members in carrying stresses.

For this reason, repairs to the skin must restore the original strength just as do repairs to ribs, bulkheads, spars, or stringers. Since the skin is on the surface, it

is exposed to damage from various sources—from gun fire or collision, vibration, corrosion. Corrosion is often evident only when a thorough inspection is made of the skin. Then too, an excessive number of patches or minor repairs on a section of a fuselage, wing, or control surface may require its replacement.

LOOK IT OVER

Make your inspection of the damaged area thorough enough to determine damage other than obvious skin failure. Take off the paint around the damaged area so that cracks or other indications of stress can be discovered. When you do this, use a paint remover or solvent that won't injure the corrosion resistant coating on the part.

Then inspect the reinforcing rings or stringers for damage or for signs of strain. If you find that any of

Figure 166.—Sheared rivet.

these members are bent, fractured or wrinkled, they must be replaced or repaired. Look over the rivets in the area for signs of failure—it is possible that they may be sheared considerably without any visible signs being present. The way to check on such shearing is to drill out rivets at various points in the damaged area and examine them for signs of shear failure. Figure 166 shows a rivet that has been sheared. It would fail if it were not replaced.

After you have discovered the extent of the damage, you can figure out the size of the new sheet. If the

damage is not great enough to require replacement of the entire original panel, the replacement should extend at least from one reinforcement to another as in figure 167.

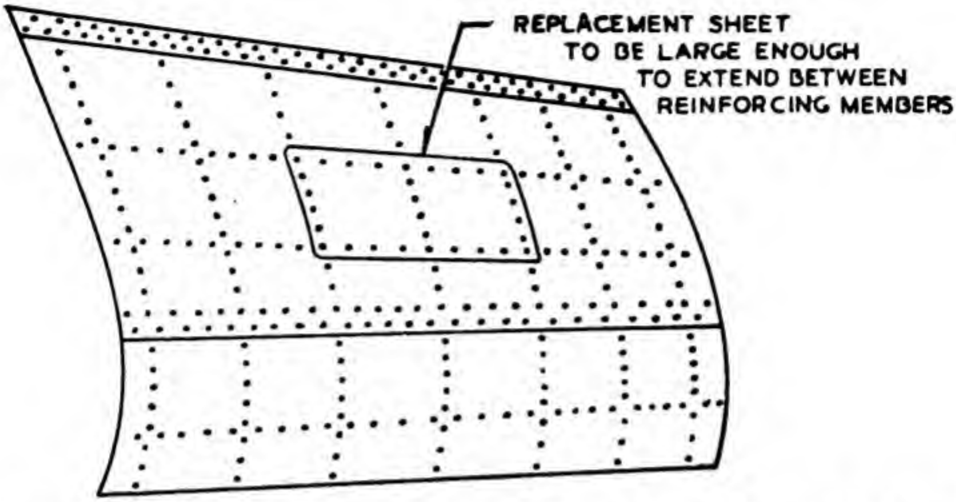


Figure 167.—Size of replacement when entire panel is not removed.

Your inspection should also reveal to you any condition which makes riveting difficult or which might make replacement impossible. A thorough inspection job is time well spent even if it shows you nothing more than the fact that repairs must be done at an A. and R. shop or at the factory because of the special tools required.

One thing you will find out from your inspection is the existence of any fixtures which might hinder riveting or prevent the use of straight bucking bars. You may also find places where it would be very difficult to buck rivets at all. Such places might be spots where there are flanges or reinforcing members or where stringers and rings intersect. These problems will govern the design of your repair. You may even find it necessary to make special bucking bars to suit the riveting requirements of the situation.

Be very careful to avoid mutilating the damaged skin as you remove it. In other words, TAKE IT EASY. Often this damaged skin can be used as a template for laying out and drilling holes in the new piece of skin.

Needless to say, you will want to keep the rivet holes in stringers, bulkheads, rings and so forth, in as good condition as possible. If any of the reinforcing members are loosened by the removal of rivets, mark their location so that they can be returned to their original position when the repair is made.

PREPARE THE REPLACEMENT SHEET

Before you prepare it you've got to select it. And in selecting the replacement sheet, you must take these factors into consideration.

The replaced skin should restore the original strength to the surface, since, as you know, the skin is a structural member of the aircraft and as such carries a part of the stress.

The replacement sheet should not be so thick that it adds excessive weight to the airplane.

It should have the same qualities of corrosion resistance as the original skin.

It should be made of a material that allows you to duplicate the original contour of the section being replaced.

These are the factors you must consider in deciding the material to be used for the replacement. This means that 2S must be replaced with 2S, 24ST with 24ST, and Alclad with Alclad in order to restore the original strength and durability of the skin.

You may use either of two ways to determine the size and shape of the replacement piece. You can either measure the dimensions necessary during your inspection of the damage, or you may use the old skin as a template for the layout of the sheet and for the location of the holes. This last method is more accurate. Cut the new sheet to a size which includes an allowance of one or two inches of material outside the rivet holes.

After you have trimmed the new panel to the same size as the original, figure the size, location, number of rows and number of rivets to match those on the sheet

being replaced. This is a safe practice to follow since these specifications are based upon the designer's knowledge of the skin stresses and of the strength required.

There are several ways to drill the rivet holes. One way is to use the old sheet, if it is not too badly damaged, as a TEMPLATE.

Take the new sheet—which has been cut approximately one inch larger than the old—and fasten it to the previously flattened old skin with C clamps. Then drill one or two holes near the center of the new sheet using the holes in the old sheet as a guide.

Next fasten the sheets together with sheet metal fasteners. DO NOT use sheet metal screws for this purpose because they injure the edges of the rivet holes. In drilling the rivet holes, proceed from the center to the outside of the sheet, inserting sheet fasteners at frequent intervals as you go along.

If you find that you cannot use the old sheet as a template, you may drill the holes in the new sheet by placing it upon the framework and drilling from the inside of the fuselage. With this method, the holes in the reinforcing members of the fuselage are used as guides.

Before you place the new sheet on the framework to drill the hole, BE SURE that the stringers and rings, or bulkheads, are properly alined and that they are flush at the points where they intersect, otherwise the holes in the new sheet will not be accurately alined.

For the same reason, you must see that the new sheet has the same contour as the old one before you drill the rivet holes.

Again, start drilling the holes in the center of the new sheet and work to the outside in order to lessen the danger of objectionable buckles and wrinkles. You will need a partner to help you drill the holes so that they are accurately alined. One of you should do the drilling while the other holds a block of wood against the outside with enough pressure to hold the skin tightly against the bulkhead or stringer.

You may find it necessary to use an angle drill in places where it is impossible to insert a straight drill. But sometimes you'll find you can use neither an angle nor a straight drill. What to do?

Mark spots for the holes in the new section THROUGH the holes in the old section. Work VERY CAREFULLY and use a soft pencil. The center of the pencil mark must be EXACTLY in the center of the hole. Another way to mark the location of the new holes is to use a sharp pointed instrument like a transfer or prick punch, shown in figure 168. Center the instrument in the old hole and

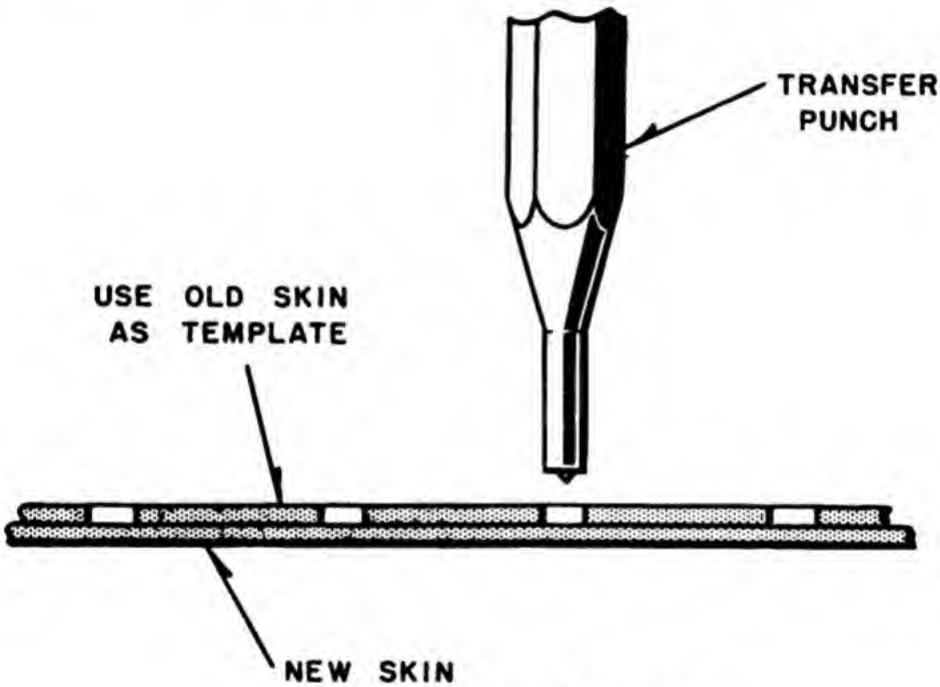


Figure 168.—Transfer punch.

then hammer lightly on the outside of the sheet with a mallet. The result should be a mark which will serve to locate the hole in the new sheet.

Still another way to locate the rivet holes without a template is to use a HOLE FINDER, similar to the one shown in figure 169. This device makes it possible for you to drill holes in the new section of skin which are perfectly alined with holes in the sheet still in place.

The hole finder comes in two sections—an upper and

a lower part which are bolted together at one end. At the free end of the bottom section of the hole finder you have a GUIDE RIVET. This guide rivet drops into the old holes in the sheets still in place. (Remember, you have DRILLED OUT the rivets from these holes in order to remove the damaged section.)

The free end of the top section of the hole finder has a hole whose position EXACTLY MATCHES the position of the guide rivet. You drill the new hole through this opening. Thus, as you slide the hole finder along, the guide rivet drops into an old hole and automatically determines the position of the new hole. Some hole

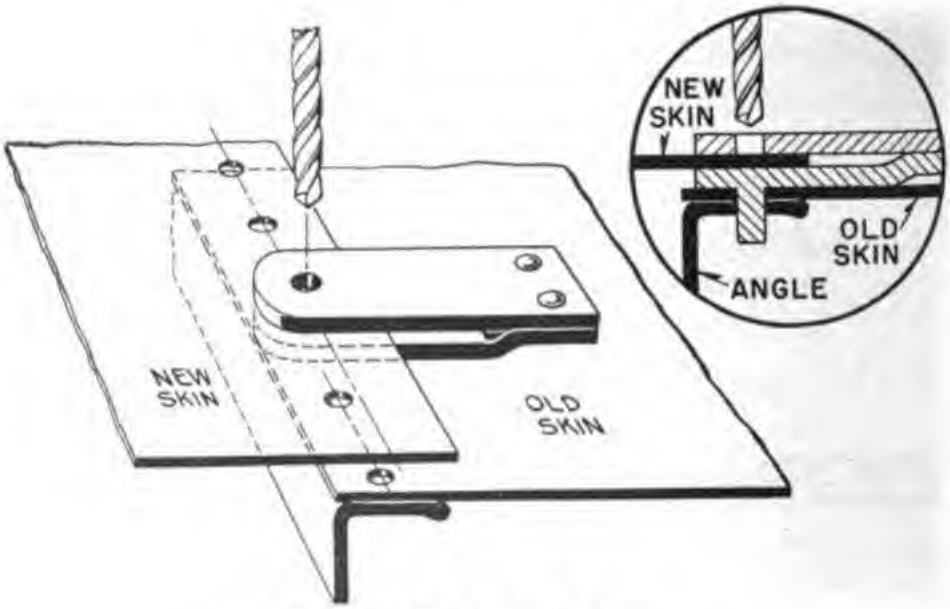


Figure 169.—A hole finder.

finders have a sharp punch in the end of the top section instead of a hole. It is used to MARK rivet locations instead of being a guide for actually drilling the new holes. You must, of course, have a separate hole finder for EACH SIZE of rivet.

After you have drilled the holes, mark the edge distance and cut the sheet to exact size. Remove all burrs from both the holes and the edges so that the sheets can be held tightly together permitting the rivet head to seat properly. Remember to apply a coat of zinc

chromate to those parts of the sheet that you won't be able to reach after they are riveted.

DRIVE THE RIVETS

One of the most important factors in the success of your riveting job is the selection of the proper type and weight of BUCKING BAR. For instance, a bucking bar

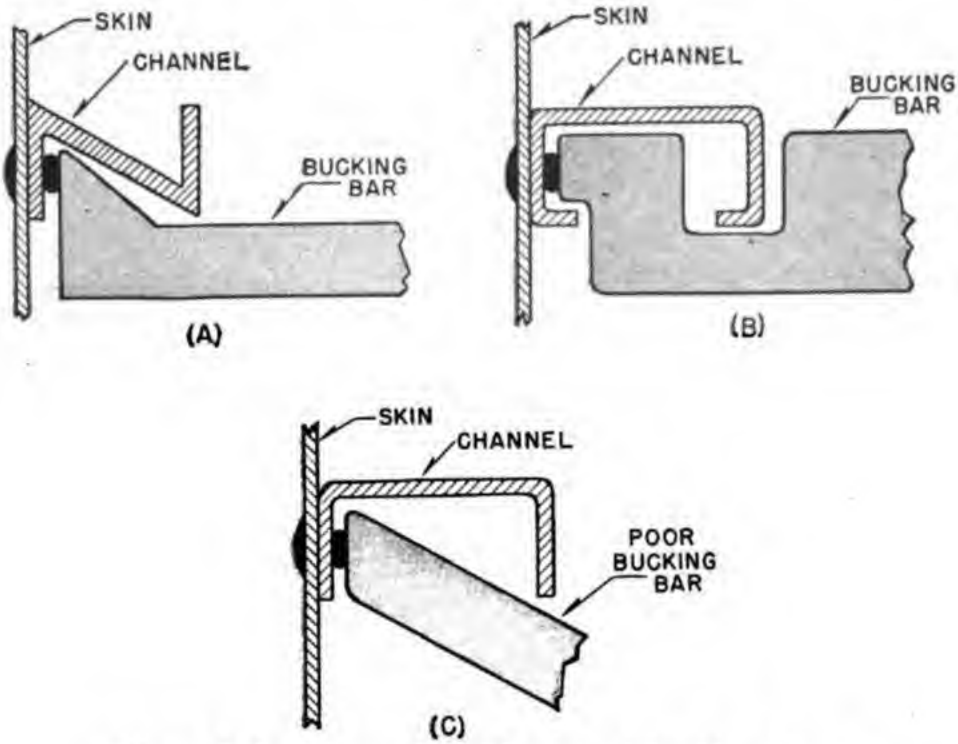


Figure 170.—Correct and incorrect bucking bars.

for 1/8 inch rivets should weigh AT LEAST two pounds. Bars for larger rivets should be proportionately heavier. Too light a bar is bad because it takes too many blows to upset the head of the rivet and the result is a hardened, clinched head, or wrinkled skin around the head.

Whenever possible, use a STRAIGHT bar so that the weight of the bar can be applied directly in line with the shank of the rivet. Where flanges on ribs or stringers will not permit the use of a straight bucking bar, you should devise one that will allow pressure to be applied in a straight line with the rivet like those in (*A*) and

(*B*) of figure 170. These bucking bars give much better results than one with a beveled end like that in (*C*) of figure 170.

In the riveting sequence it is frequently desirable to drill and rivet as you go. That is, drill one or possibly two holes at a time, drive rivets into them, and then proceed along the joint in the same manner. This procedure helps to prevent buckles in the sheet between rivets and also eliminates "oil cans" in the sheet.

Start the drilling and riveting of the replacement panel at the CENTER. Rivet every third or fourth hole, working out toward the edges. When you get to the edge go back and rivet the remaining holes.

The rivets you drive should, of course, have the same type of head as the ones being replaced—that is, replace brazier head rivets with brazier heads and so forth.

Use enough pressure on the pneumatic gun so that the rivets can be upset with as FEW BLOWS as possible in order to avoid strain hardening, When you get through riveting, apply a coat of zinc chromate primer to the inside and outside of all surfaces.

CHAPTER 6

TANKS

BASIC INFORMATION

In general, there are two types of fuel and oil tanks in use on aircraft. One is the ordinary METAL TANK. The other is the SELF-SEALING tank.

The metal tank may be made of various kinds of sheet metal, including aluminum, terneplate, copper, brass, monel metal, or stainless steel. It may be REMOVABLE—that is, capable of being taken out of the location for repair—or NON-REMOVABLE, in which case it is known as an INTEGRAL tank.

INTEGRAL TANKS are a part of another structure, such as a wing, hull, or float. In this case the metal surface or skin of the structure serves also as the SHELL OF THE TANK. The advantage of this type of construction lies in the saving of weight and streamlining of design which results from the combination of functions of the structure. In repairing the integral tank, you are, of course, repairing the skin of the structure of which it is a part. In figure 171, you see examples of the two types of METAL TANK.

REPAIR OF ALUMINUM TANKS

Sheet metal is used in the construction of most fuel tanks, but those on Naval aircraft are built chiefly of ALUMINUM. While this material is rather difficult to repair, its great advantage of lightness in weight more than offsets the repair difficulties. The following will outline for you the repair procedures for tanks made of aluminum. Methods of repair for this type of metal

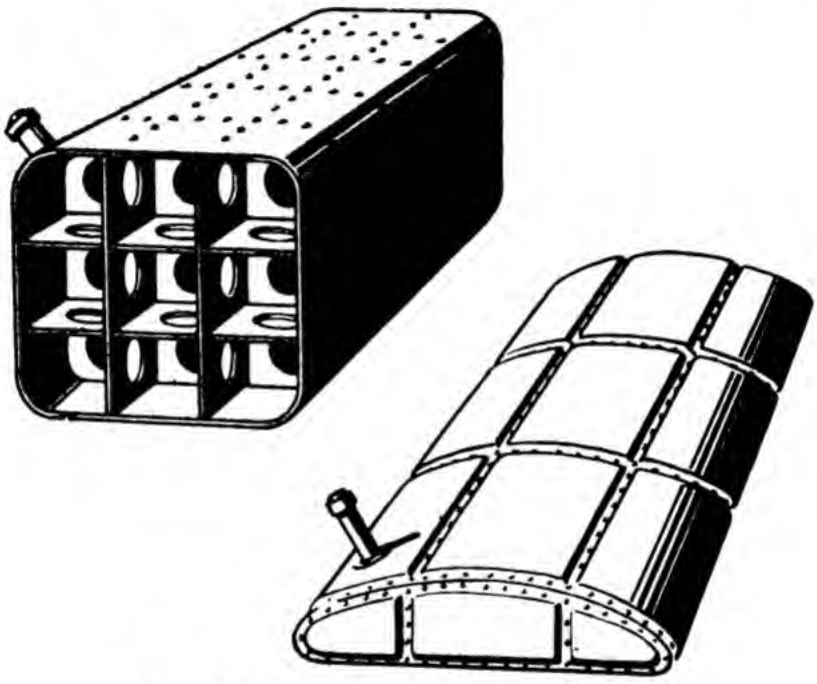


Figure 171.—Types of metal tanks.

tank can also be applied to tanks made of other kinds of sheet metal.

Repairs on aluminum tanks may be made by WELDING, or if the tank is nickel plated, by SOLDERING and by RIVETING.

WELDING REPAIRS

To repair REMOVABLE metal tanks, begin by removing the tank and examining it carefully to determine the location of the leak. If the tank is WELDED, close all openings in the tank but one, then fit an air hose to

this opening and place the tank under an air pressure of 2½ pounds. Cover each SEAM RIVET, and FITTING WITH SOAPY WATER. The pressure of air in the tank will cause bubbles where repair work is needed. These spots can then be marked with chalk.

If any of the leaks discovered in the tank are to be REPAIRED BY WELDING, your next step is to CLEAN THE TANK THOROUGHLY to eliminate any DANGER OF EXPLOSION during welding. To do this, flush the tank for one hour with HOT WATER, admitting the water at the bottom of the tank and allowing it to overflow at the top. Since oil and gasoline are lighter than water, they will rise to the top and flow off in the overflow. During this operation most of the oil and fuel adhering to the sides of the tank will be removed.

The other type of tank used in modern aircraft, which you see illustrated in figure 172, is known as the

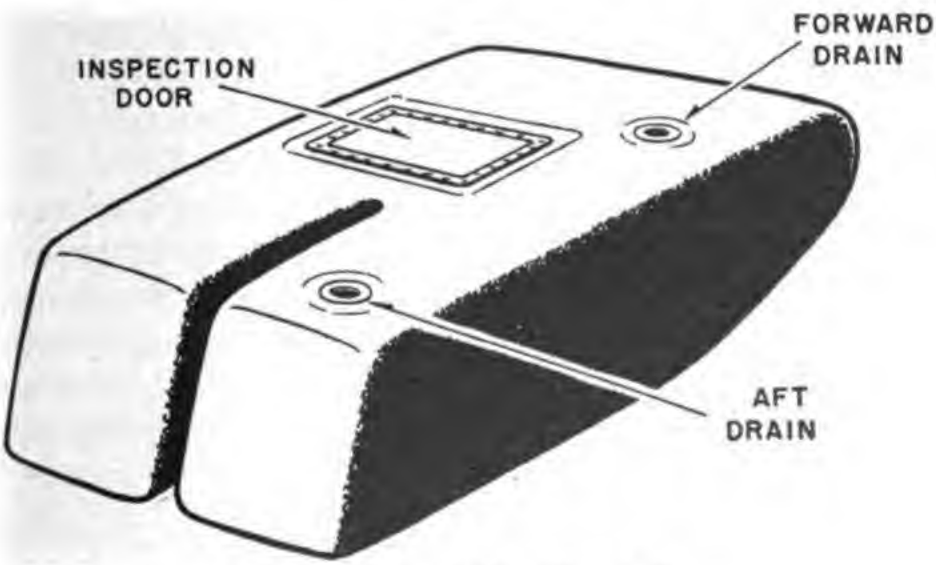


Figure 172.—Self-sealing cell.

SELF-SEALING TANK, and consists of two parts, the outer METAL SHELL and the inner SELF-SEALING CELL. The self-sealing cell fits into the metal shell like an inner tube into a tire, and has three parts—a gasoline resistant inner layer, a middle layer of sealant, and a more rigid, tough outside layer. Whether the metal

shell of this type of tank is removable or non-removable (integral), the self-sealing cell may be taken out of the shell for repairs.

The type of construction for fuel and oil tanks varies with every class of airplane. The shape and size of the tank depends on the type of metal from which it is constructed and upon its location in the aircraft. Because of these differences, the same maintenance procedures do not apply to all types of tanks. If possible, always consult the TECHNICAL NOTES, TECHNICAL ORDERS, SPECIFICATIONS, and MANUFACTURER'S HANDBOOKS for detailed instructions regarding the repair of your specific type of tank. Since there will be times when this information is not available, however, particularly under emergency conditions, you should know the basic principles and practices which apply to ALL repair work on metal and self-sealing tanks.

To remove the REMAINING FUEL AND OIL, place the tank on a bench or stand. After closing all openings except one at the top and one at the lowest point in the tank, feed LIVE STEAM into the tank at the top opening, allowing it to escape through the bottom for a MINIMUM PERIOD OF THREE HOURS. If you do not have the equipment for steam cleaning, pass hot water through the tank for a MINIMUM PERIOD OF ONE HOUR, then thoroughly dry out the tank by circulated compressed air through it with a hose. Since this method, however, is not as thorough a means of removing combustible material and fumes as steam cleaning, DON'T USE IT unless absolutely necessary.

If the interior of the tank is to be cleaned with paint remover or any other combustible solvent, do this cleaning before flushing and steaming the tank. When the tank has been carefully cleaned, as outlined, you are ready to begin the welded repairs.

NICKEL PLATED ALUMINUM TANKS can be repaired by SOLDERING provided the nickel has not been scratched off. Use paint remover to clean off any paint or oil from the nickel plate, but DO NOT attempt to clean it with a

WIRE BRUSH or SCRAPER, because they will damage the nickel plate.

When nickel plated tanks are repaired with a soldering iron, it is NOT NECESSARY TO CLEAN THE TANK WITH WATER OR STEAM, PROVIDED THAT ALL FUEL OR OIL has been completely drained. In using this repair method, be careful not to heat the soldering iron to a temperature that will cause particles of dust to become incandescent. Such particles are sufficient to ignite any explosive mixture left in the tank.

NEVER make any repairs requiring the application of heat (including soldering) on fuel or oil tanks WHILE THEY ARE INSTALLED in aircraft, and DO NOT perform any welding operations near combustible materials. "EMPTY" GASOLINE CONTAINERS ARE AS DANGEROUS AS HAND GRENADES!

RIVETED REPAIRS

The seams of many aluminum alloy tanks are fastened by riveting rather than welding.

When you wish to find a leak in a riveted tank, CLOSE all openings except the sump connection or the filler opening and apply air pressure not greater than 3½ pounds per square inch to the tank. Then lay the tank on its side in a shallow tray filled with light machine oil to a depth of approximately three inches. Now turn the tank over slowly in the liquid and look for bubbles. These bubbles will form at the spots needing repair.

Because no heat is required for riveted repairs, such tanks SHOULD NOT be first cleaned with water or steam. The reason for avoiding water or steam in a riveted tank is that the seams of such tanks are filled with a SEALING COMPOUND. Hot water or steam LOOSENS this compound and causes the leaks to spring out in the seams like in a sprinkling system.

MINOR SEEPAGE or VAPOR LEAKS in the tank may be repaired with an EXTERNAL application of THIOKOL

G-18 or similar compound. Before you apply Thiokol, however, clean all the grease and dirt from the area to be treated and brighten the metal with steel wool. Then use a small paint brush, such as a sash brush, and apply the Thiokol, using a thick coat of the substance. Allow this coat to dry for approximately 30 minutes before brushing on another coat about $\frac{1}{16}$ inch thick. This last coat should be allowed to dry about 48 hours.

For the first few hours of drying be sure that the tank is placed in such a position that the freshly applied compound will not flow away from the treated area. After the 48-hour period, test the tank as before in the tray of oil or water, using $3\frac{1}{2}$ pounds of air pressure in the tank.

Open or split seams which cause DRIPPING OR RUNNING LEAKS, CANNOT be treated effectively with Thiokol alone. You must first DRILL OUT all damaged or loose seam rivets near the leak. Then, working towards the damaged area from both sides, tighten the remaining rivets along the seam for a distance of about 3 inches. A pneumatic squeeze riveter should be used, if possible, for this operation and also for the replacement of the new rivets. All new rivets should be dipped in Thiokol before they are driven.

After you have tightened the old rivets and replaced the others with new rivets where needed, apply Thiokol along the seam and around the rivets in the same manner as described for stopping minor seepage.

If, upon testing the tank, you find that the leaks have not been completely stopped, it may be necessary to apply Thiokol to the INSIDE SEAM. To do this you may have to cut a HANDHOLE in the tank to provide access to the seams requiring the compound. Whenever it is necessary to make such handholes, they should be cut in the flat top surface of the tanks, if possible in a location that will not interfere with the structure of the airplane.

If the tank has a small seepage or vapor leak around a BULKHEAD RIVET, it may also be treated with an ap-

plication of Thiokol. However, if the bulkhead rivet is loose or located near the bottom of the tank where it is subjected to pressure of the fuel, it is advisable to replace it with a new rivet dipped in Thiokol.

To get at such a rivet, remove the sump fittings and filler, or, if you cannot get at it through these openings, cut a handhole. Then drill and chip off the external rivet head of the faulty rivet and remove the seal washer Drive the remainder of the rivet into the tank and shake it out through the handhole or fitting opening.

Now dip a new rivet in Thiokol and insert it from the inside. Replace the external seal washer with a new coat of Thiokol on the bottom of the tank. Drive the rivet and apply Thiokol to the inside of the tank. Test for leaks after 48 hours.

INTEGRAL TANKS

Integral fuel tanks, which form a part of the wing, hull, or float of an aircraft, have RIVETED SEAMS which are sealed with a VARNISH COMPOUND. As pointed out before, moisture loosens this compound and therefore STEAM CLEANING SHOULD NOT BE APPLIED to such tanks. Before any repairs are attempted, be sure that the varnish compound adheres tightly to the inside of the tank. The best way to insure this condition is by THOROUGHLY DRYING the tank.

To dry an integral tank, first remove all handhole covers, then pass a current of compressed air, not exceeding 100° F., around and through the tank with a rubber hose. Continue this operation for a number of hours, possibly overnight, until the tank is dry.

Since it is impossible, however, to remove EXPLOSIVE FUMES by drying, NEVER try to repair integral tanks by welding or other application of heat.

To locate a leak in such a tank, apply air pressure of approximately 2 pounds to the inside of the tank, and cover the outside seams with soap suds. Bubbles will form at the spots needing repair.

If the leak is located in an accessible part of the tank, don't try to stop it by merely applying a fresh coat of varnish compound. Instead, DRILL OUT THE OLD RIVET AND TWO OR MORE RIVETS ON EITHER SIDE. After removing the rivets, soak a piece of COTTON TAPE in varnish compound and calk the area to be repaired. Coat the new rivets with the compound and drive tightly.

Rivet heads SHOULD NOT BE REMOVED WITH A CHISEL. This will elongate the rivet holes. Drill them out.

Next, using a spray gun with the nozzle bent so that the spray can be directed to the desired position, spray the leaking portion of the tank with varnish.

Spray the leaking portion thoroughly, but no heavier than necessary. If you haven't the spraying facilities, apply the varnish with a brush. After a period of 30 to 40 minutes remove any excess varnish which has drained to the lowest parts of the tank, then allow the tank to dry for 12 or more hours and repeat the varnishing and drying procedure. If the leak is very bad, THREE COATS may be necessary.

One disadvantage of the integral fuel tank is that because of the drying out of the sealing compound, it has a tendency to develop numerous leaks if allowed to stand empty for any considerable length of time. To prevent this, the tanks should be refilled as soon as possible after they are emptied.

SELF-SEALING FUEL CELLS

Combat airplanes are equipped with self-sealing tanks that are effective against the damage of machine gun bullets and even single hits with a 20 mm shell. These fuel cells are not bullet proof; they're merely puncture sealing. When the wall of the cell is punctured, the sealing material—which makes up the center layers of the cell walls—softens and expands when it comes in contact with gasoline, closing the puncture. This prevents loss of fuel, and eliminates the danger of fire.

At present three types of self-sealing cells are in use, but Naval aviation is concerned with only two of them —the STANDARD cell and the PLIOFORM cell.

The earlier type cells used by the Navy were not fully resistant to the effect of high octane fuels. The inner line was "sloshed" or coated with a liquid compound to make them gasoline resistant. More recently, Buna-N synthetic rubber, backed with nylon, has been used as the inner liner of fuel cells. This inner liner is aromatic resistant, and does not require sloshing.

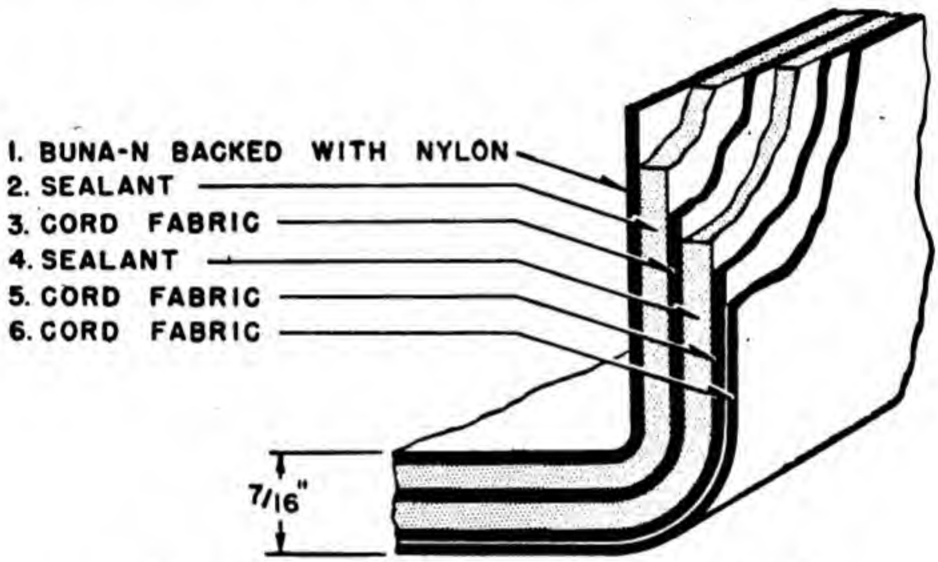


Figure 173.—Construction of standard cell.

The different layers of the cell wall of the standard type construction with the approximate thickness are shown in figure 173.

CELL LAYERS

The first or inner ply of the cell wall is the gasoline resistant layer of Buna-N which acts as a container for the gasoline.

The second ply is one of the two sealant layers. It is made of a special type of soft rubber. When in contact with fuel, this rubber "gums up" and swells to several times its normal size, preventing further escape of the gasoline from the cell proper.

The third ply is a layer of cord fa ic, cotton or rayon, impregnated with rubber. Its co s run lengthwise of the cell. This layer of fabric act as a stiffener for the two sealant layers.

The fourth ply is the second layer (sealant—exactly like the second ply.

The fifth ply is the same material as he third, but the cords run at a 45-degree angle to he length of the cell.

The sixth (or outside) ply is the sam as the third and fifth plies, but the cords run at a 9(-degree angle to the cords of the fifth ply. As a prote tive measure, the outside ply is coated with synthetic r bber for protection against spillage of fuel.

OTHER CELL PARTS

In addition to the cell plies, other parts such as fittings, stiffeners, baffles and flapper valves are used in

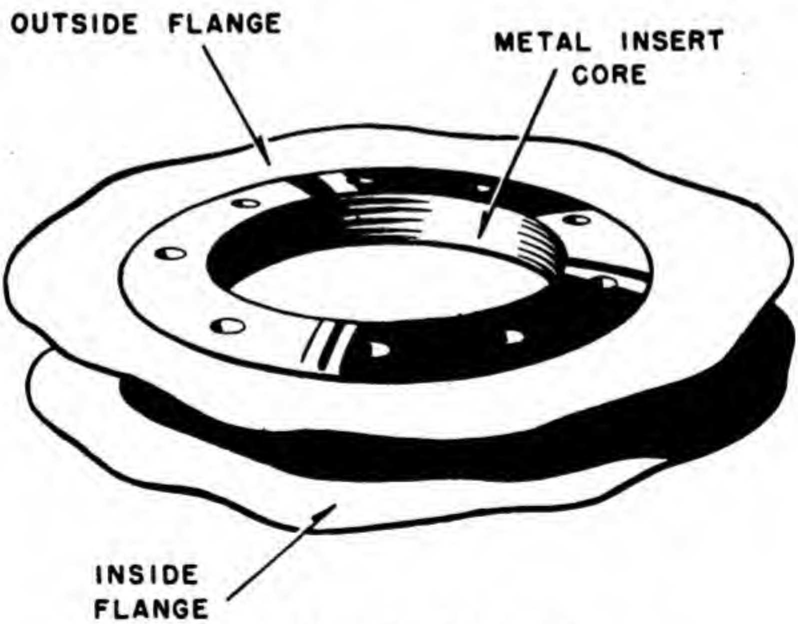


Figure 174.—Hand-hole fitting.

the various types of cells. These parts are installed during the construction of the cell.

Fittings are the openings, and are molded directly

into the cell wall. They are considered a permanent part of the cell. Each cell has a required number of fittings, depending upon the size and location of the cell of which they're a part. These are composed of three parts—inside flanges, outside flanges, and the core—and are made from synthetic gasoline-resistant rubber.

Almost all self-sealing cells are reinforced on either the inside or the outside, the size of the cell being the determining factor on whether reinforcement is necessary. Standard cells are generally reinforced from the

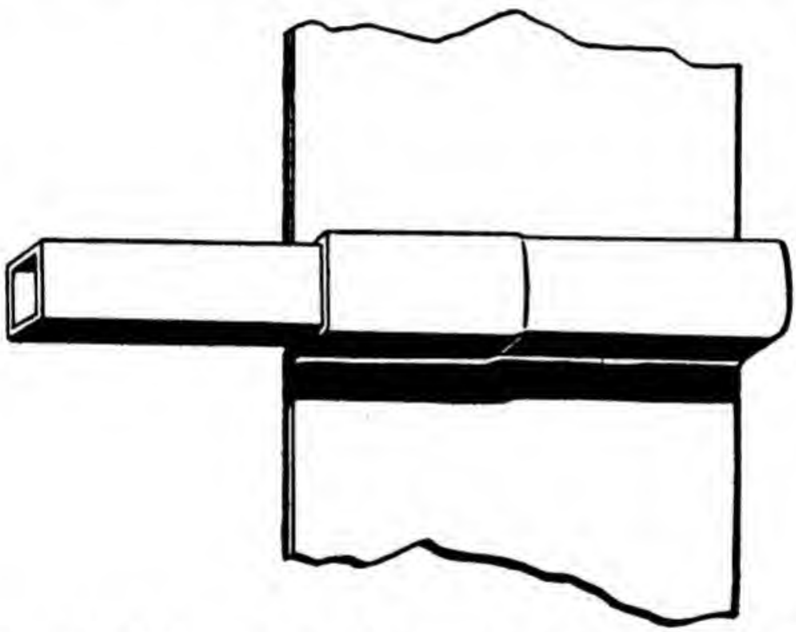


Figure 175.—Stiffener tunnel showing insertion of stiffener tube.

outside. This type of stiffener includes a fabric holder cemented to the outer surface, and a removable metal insert.

At present, some but not many Navy cells are constructed with baffles or flapper valves. Baffles are so made that they can be removed entirely, or else be collapsed with the cell.

The removable type are constructed of a heavy plastic material, such as armite or lastite, covered with fabric. The collapsible baffle is made of the same material as the cell and is built into the cell wall.

Baffles prevent or break up pressure waves, reinforce the cell wall, and keep the fuel equally distributed in all compartments.

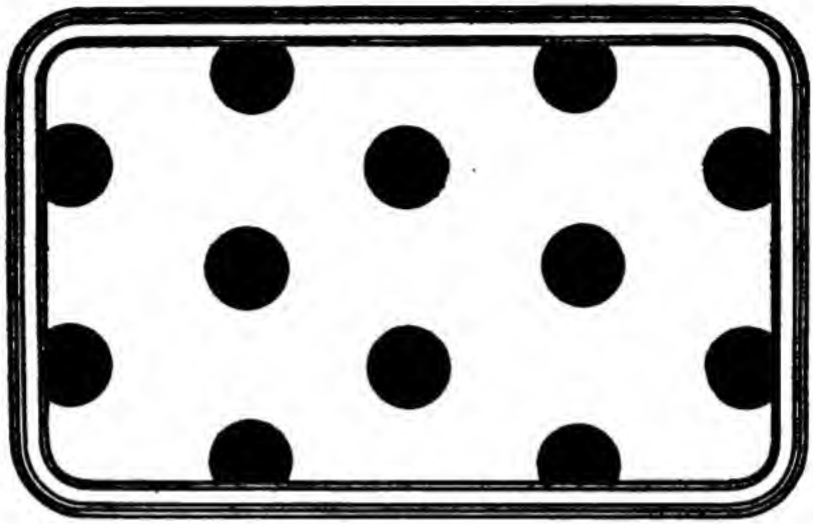


Figure 176.—Baffle.

Flapper valves are attached to the baffles. They consist of small frames with an opening in the center, plus a hinged door—all made of hard fiber or plastic material.

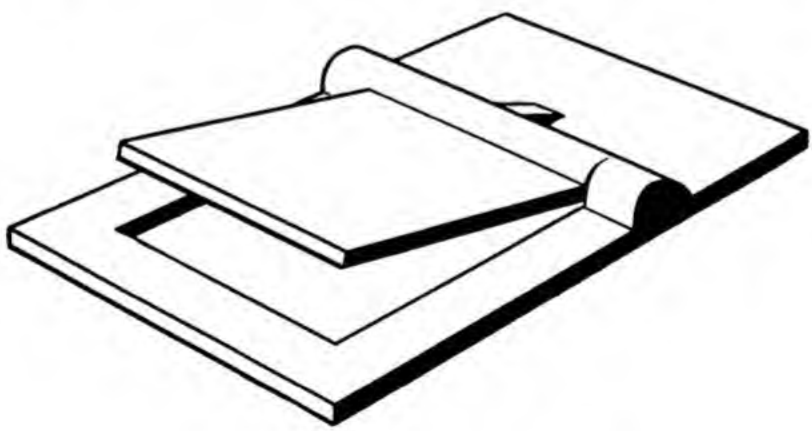


Figure 177.—Flapper valve.

rial. They control the flow of fuel from one compartment to another. Baffles and flapper valves are used mostly in combat planes.

MAKING REPAIRS

When a cell has been damaged, its self-sealing action can not be depended upon for more than a very SHORT TIME. The cell must be repaired as soon as possible, to prevent the gasoline from deteriorating the sealant.

The effectiveness of any self-sealing cell repair will depend largely upon how you size up the injury, the use of the proper methods, and the choice of repair materials. Injuries will vary from minor punctures, which may be repaired easily, to extensive shrapnel ruptures which may be difficult or impractical to repair.

The permanent repair procedure can be one of five types—

FLAT PATCH REPAIR is divided into minor or major repairs. The MINOR REPAIR is made on slit-type injuries of 2 inches or less, with one patch on both the inside and outside. The MAJOR REPAIR is the same as the minor repair, except that the injury is larger than 2 inches (and up to 10 inches).

BUILD-UP REPAIR is made on both the standard and non-metallic cells when a piece of the cell is missing and must be replaced. It is necessary to replace the missing section with sealant layers, and cover it with two patches (on both the inside and outside of the cell).

CORNER REPAIR is just what its name indicates. (It is not advisable to repair any corner injury that's over 2 inches long.) Two patches are applied, one on the inside and one on the outside.

SEAM OR LAP REPAIR is generally made on the inside of the cell, to prevent the separation of the inner liner from the first sealant layer.

BLISTER REPAIR is made only on the inner liner. This type of an injury is indicated by a swollen area on the inside of the cell.

SIZES OF PATCHES

The disk-type patch has been found most desirable

for cell repairs, in view of the fact that it eliminates corners, assures complete coverage of the injury, and can be manipulated to fit corners.

In general, a patch should overlap the injury on the inside a minimum of 2 inches. With the use of two patches, the first will overlap the injury by 1 inch, and the second patch will overlap the first by 1 inch, thus covering the 2-inch cut.

The outside patch would have an overlap of 2½

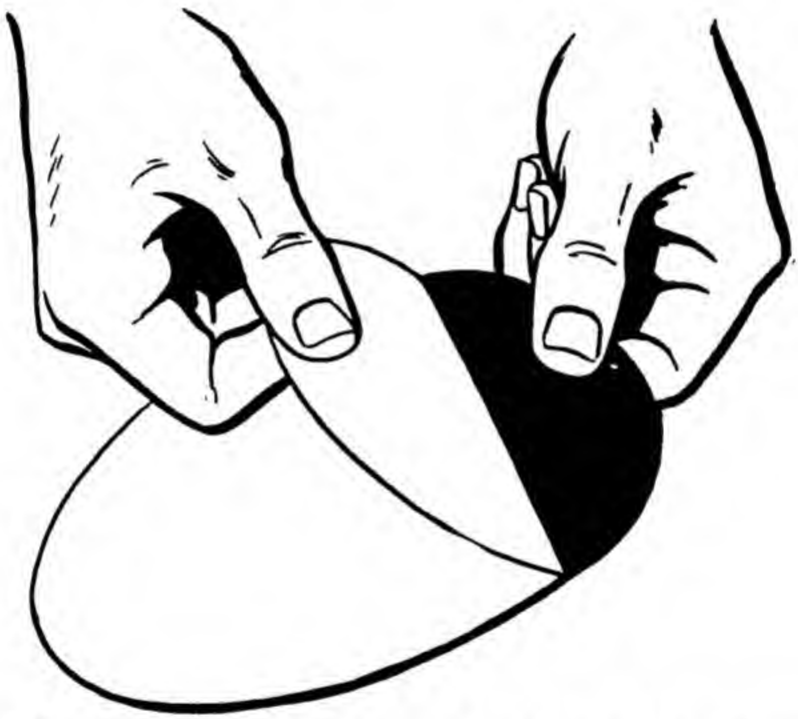


Figure 178.—Disk patch (inside repair gum, holland cloth covering).

inches over the injury for the first patch, and if a second patch is required (as in the major repair) this patch should overlap the first by 1 inch. All laps are measured from the injury to its longest point. Refer to Table XII for the various buffing areas and patch sizes for each repair.

TOOLS AND EQUIPMENT

Figure 179 shows the tools needed for all permanent

TABLE XII

Types of Repairs	Buffing Area		Patch Sizes			
	Inside	Outside	Inside		Outside	
Permanent Repairs			First Patch	Second Patch	First Patch	Second Patch
Fitting	2½″ beyond flange	2½″ beyond flange	Edge of core 1″ off flange	Edge of core 2″ off flange	Edge of core 2″ off flange	None
Flow Tube	2½″ beyond flange	2½″ beyond flange	Edge of Core 1″ off flange	⅛″ on tube 2″ off flange	⅛″ from core opening; 2″ off flange	None
Minor (Under 2″)	2½″ beyond injury	3″ beyond injury	2″ beyond injury	None	2½″ beyond injury	None
Major (Over 2″)	2½″ beyond injury	4″ beyond injury	2″ beyond injury	None	2½″ beyond injury	3½″ beyond injury
Corner	2½″ beyond injury	3″ beyond injury	1″ beyond injury	2″ beyond injury	2½″ beyond injury	2½″ diam.
Blister	2½″ beyond injury	None	2″ beyond injury	None	None	None
Seam	2½″ beyond injury	None	2″ beyond injury	None	None	None
Standard Build-Up	2½″ beyond injury	5″ beyond injury	1″ around injury	2″ around injury	2½″ beyond sealant	3½″ beyond sealant
Plioform Build-Up	2½″ beyond injury	6½″ beyond injury	1″ beyond injury	2″ beyond injury	2½″ beyond sealant	3½″ beyond sealant

repairs. The following list includes both tools and equipment—

8- or 10-inch shears
¼-inch stitcher
Gooseneck stitcher (1/32-inch)
Skiving knife
Mill knife, with removable blade
Pneumatic buffer
Rotary files (1 x 1 or 1 x 2)
Emery sleeve mandrel (1 x 1)
12-inch ruler
8-inch dividers or compass
Cement cup (1 pt.)
Cement brush
Inspection mirror
Emery cloth (#40, #80)
Vaporproof light extension cord
White chalk
Clean rags
Can of safety solvent.

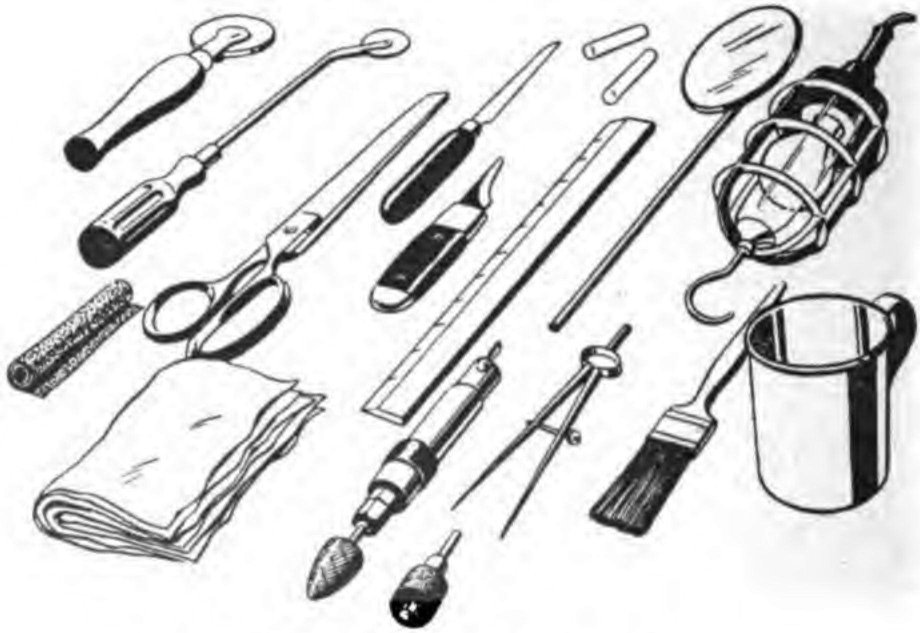


Figure 179.—Tools for repair.

REPAIR MATERIALS

Since there is such limited time for repairing cells, it is important that you use the approved repair materials for the inside and outside of the cell—along with the recommended cement, accelerator, and solvent.

The inside repair gum (nylon sandwich type) consists of two thin layers of synthetic rubber with a coating of nylon sandwiched between.

The outside repair fabric is called square-woven fab-

ric. It has cords running criss-cross (or "inter-woven"), and is impregnated with synthetic rubber.

A universal cement has been compounded for use with the Buna-type inner liner. This cement can be used on both inside and outside repairs. It is called J-868 cement, and has proved to be the most satisfactory of all cements for the purpose.

The "accelerator" comes with the cement. It should be added only during mixing, and then only in the required amount. When added, it generates heat and hastens the curing process.

Solvents, such as methyl ethyl ketone or ethyl acetate, are used to clean buffed surfaces and to dissolve the cement or re-activate it before applying the cemented patch. The solvent should be the same as that used in the making of the cement.

Figure 180.—Buffing.

Always REMEMBER that rubber repair materials, cements and solvents should be stored in a cool, dry place.

REPAIR OPERATIONS

There are five main operations in making a successful repair on a self-sealing fuel cell. They are—buffing, beveling, feathering, cementing, and stitching.

BUFFING is a means of roughening (with an abrasive, by hand or power) the surface of the cell wall and patch, to provide a good anchorage for the cement.

The inner liner and the inside repair gum should be buffed until the gloss has been removed or the surface has been scratched thoroughly. The outside layer of the cell wall and square woven fabric should be buffed until the cords show through evenly as you see in figure 180.

BEVELING is the preparation of the patch edges—cutting them with shears at a 45 degree angle—to

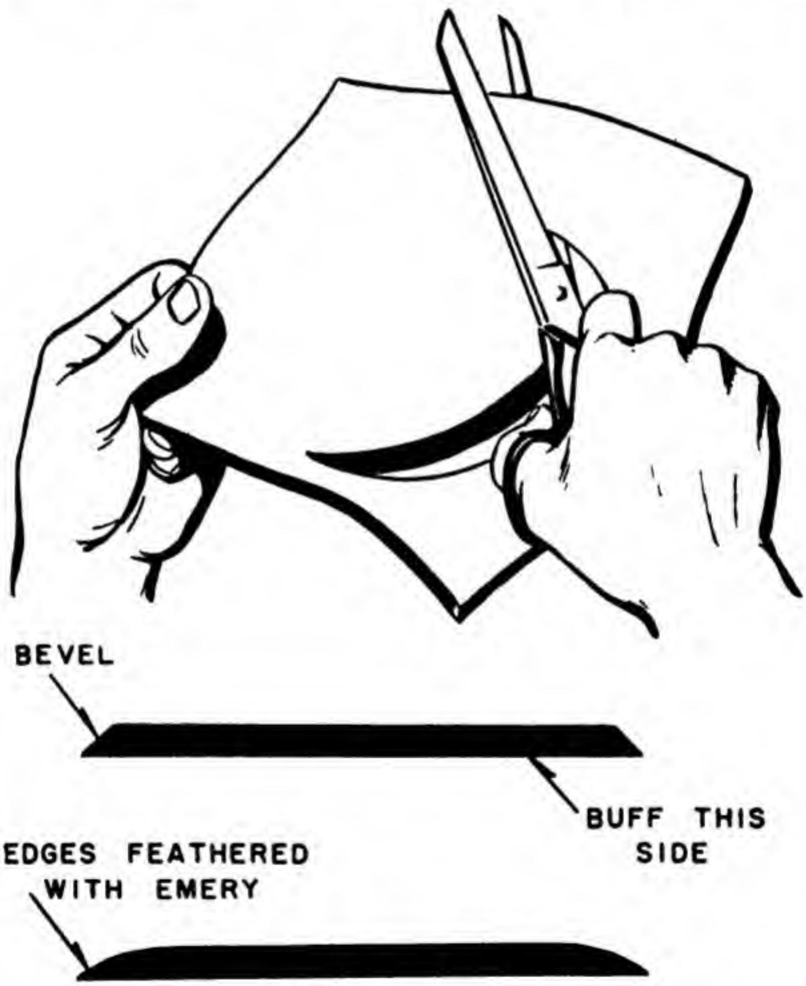


Figure 181.—Beveling.

reduce the possibility of lifting the edge. To provide full-size patches, allow from ⅛- to ¼-inch on all edges for beveling.

Feathering is a continuation of beveling, and is the last operation in preparing patch edges to paper thickness. This operation is performed on the first patch when a second patch is applied, or on the inside repair gum if and when necessary. Feathering is done by buffing a piece of tightly rolled emery cloth along the edge of the bevel.

Cementing is the application of the cement necessary for the adhesion of patches. Cement is applied with a 1-inch brush.

Cement should never be prepared until needed.

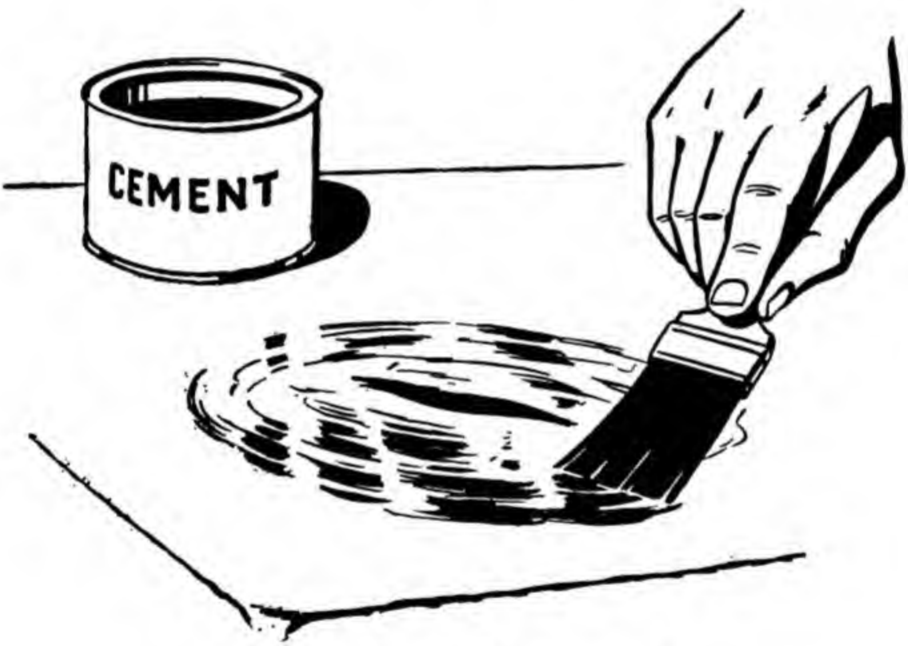


Figure 182.—Applying cement.

Here's how to do it. Mix five teaspoons (12.5 cc.) of accelerator thoroughly with one pint of cement. Stir the mixture continuously as the accelerator is added. Cement can be used from six to eight hours after mixing.

Stitching is the operation used for rolling down a patch into contact with the cemented surface of the cell wall. Different size stitchers or rollers may be used, depending upon the location of the repair.

STEP 1 STEP 2 STEP 3

Figure 183.—Applying and stitching down a patch.

REPAIRING SLIT-TYPE INJURIES

A closed or slit type injury is one extending through one or more layers of the cell. Repairing such an injury requires no replacement of materials.

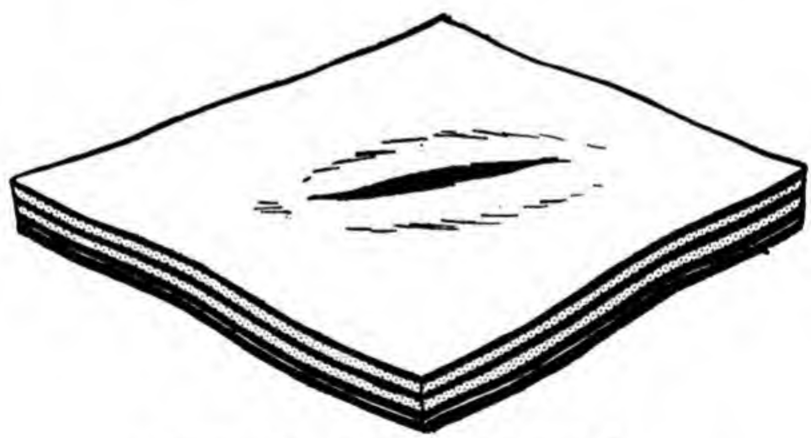


Figure 184.—Slit-type injury inside.

Drain all fuel from the cell, and remove cell from the plane. If you circulate air through the cell, you'll hasten the drying time and remove the gasoline fumes. Examine the injury and determine the type of repair needed.

Spread the opening or injury in the cell slightly to speed the evaporation of the gasoline from the sealant layers around the injury. You can start the actual repair when the sealant is no longer swollen.

Buff an area on the inside of the cell; the buffed area should extend 2½ inches in all directions from the edge of the injury. Buff the outside area for 3 inches in all directions from the cut. Buff the liner with emery cloth until the gloss has been removed, and the outer fabric until the cords show evenly. After buffing, wash the buffed surfaces lightly with a clean rag (dipped in solvent) to remove the buffing dust.

Cut a piece of inside repair gum, large enough to

Figure 185.—Drying swollen sealant.

extend 2 inches in all directions beyond the injury. Also cut a piece of outside repair fabric to extend 2½ inches in all directions beyond the edge of the cut. Buff one side of the inside patch until the gloss has been removed; and one side of the outside patch until the cords show through. Bevel the edges of each patch by tilting the shears as the material is cut. Be sure the bevel is on the side opposite the buffed surface. Wash the buffed patch surfaces lightly with solvent.

Apply two coats of cement to the inner liner and inside patch, allowing the first coat to dry thoroughly. While the second coat is still tacky, center the patch over the injury and stitch it down, being careful to remove all trapped air.

To determine if the cement is dry, press the back of the knuckle gently against the cemented surface. If, when you remove it, there's cement sticking to it, the cement is still tacky. This is called the KNUCKLE TEST.

Repeat the patch application for the outside patch.

After the outside patch has been applied, complete the repair by applying two coats of cement over the entire patch and the surrounding buffed area on the

Figure 186.—Testing cement, knuckle test.

outside cell wall. Allow each coat to dry thoroughly. The repair should air-cure a minimum of 72 hours before using.

If the injury is a major one (over 2 inches), feather the first outside patch with emery cloth before applying. Then prepare and apply a second patch, which should overlap the first one by 1 inch in all directions.

HOLE-TYPE INJURIES

When the injury consists of a hole in the cell—with a section blown out instead of a slit or a cut—you'll have to replace the material that is missing. Prepare the cell for repair as you would for a slit injury.

With your dividers draw a circle around the injury large enough to include all the damaged area, but not

smaller than 3 inches in diameter. Draw a second circle with a 1-inch radius. This second circle will give you the angle of bevel-cut. Using the same center, draw a third circle with a radius 4 inches greater than the second. This last and largest circle will give you

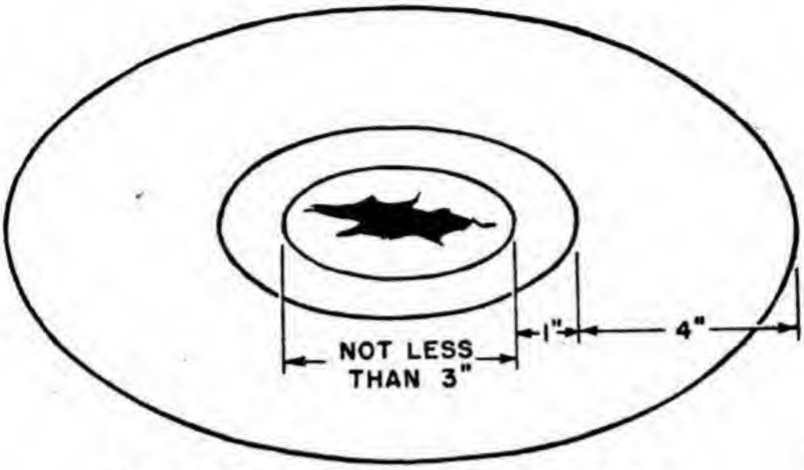


Figure 187.—Marking a hole-type injury.

the outer buffing area. On the inner liner (using the same center) draw a circle the same size as the first circle on outer side. Then, to mark the inner buffing

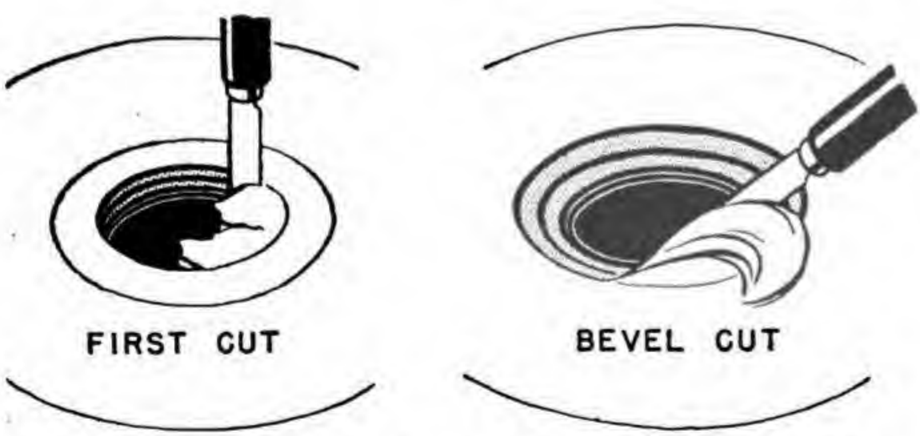


Figure 188.—Cutting away damaged section in hole-type injury.

area, draw another circle with a radius 2½ inches greater. Buff both areas.

Using the smallest circle on the outer side as guide, cut away the damaged area, holding the knife perpen-

dicular to the cell wall. Then bevel-cut the edge, using the second circle as a guide. If you will dip the knife blade in water, it will make the cutting of the cell wall easier. The result is a shallow bevel of about 30 degrees, which provides efficient adhesion surface. Smooth the beveled area.

Now build a support inside the cell under the area to be repaired, placing a piece of Holland cloth between the support and the hole. The support may be built from a section of cell wall and wood blocks.

Cut three patches from sealant material, large enough to overlap the bevel-cut by ½ inch on all sides. Roughen both sides of each sealant patch before applying. Apply the first patch with cement and wipe the next two with

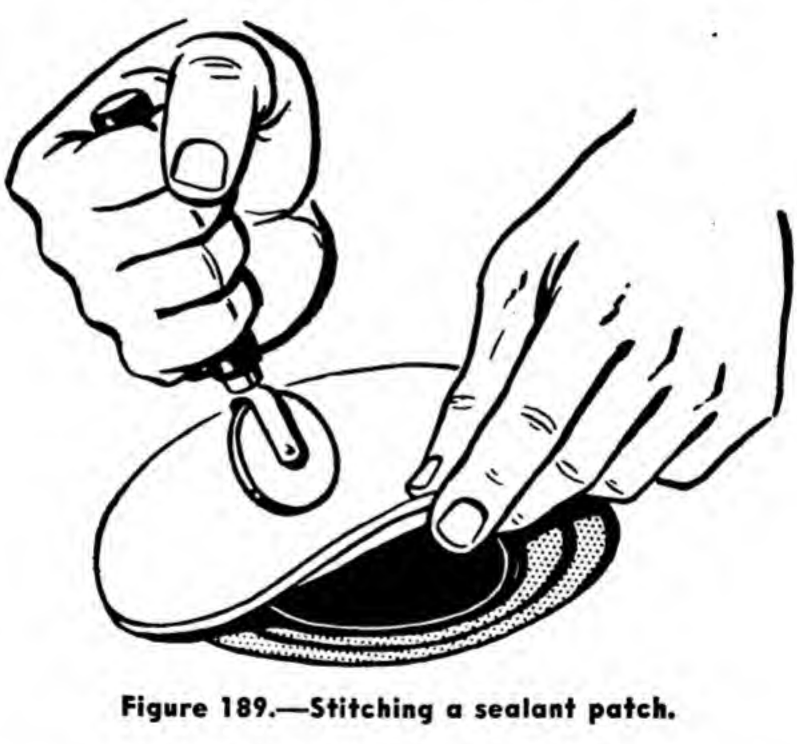


Figure 189.—Stitching a sealant patch.

texine or benzene. Avoid excess wetting. When the sealant is tacky enough to stick to itself, apply the patch layers separately, stitching each one down thoroughly. Allow the build-up to dry for several hours before completing the repair, or you will have to start over again. When the patch is thoroughly dry or cured,

trim excess sealant away so that the build-up is flush with the outer side of the cell wall.

Next, cut two outside patches—the first overlapping the sealant build-up by 2 inches, and the second overlapping the first patch by 1 inch. Apply patches in the same manner as you would for slit injuries.

After the sealant build-up has cured, remove the support from inside the cell and place a support against the outside of the repair area. A sand bag is satisfactory for this purpose. Remove the Holland cloth from the inner liner and apply two patches that have been prepared in the same manner as the outside patches. Do NOT cover these inside patches with cement when repair is completed.

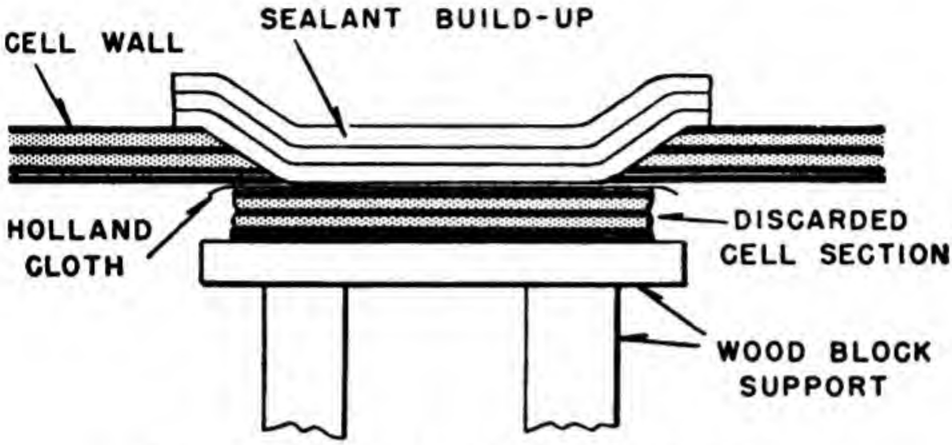


Figure 190.—Cross section of build-up repair.

BUILD-UP FOR NON-METALLIC CELLS

Because of the construction of the plioform cell, repairs on the sealing section and the retainer section are made differently.

Mark two circles on the exterior of the cell—the first circle large enough to overlap the damaged area by 2½ inches, and the second circle overlapping the first circle by 4 inches. (The second circle marks your buffing area.) Again, remember to force the divider

point THROUGH the cell wall to locate the center mark on the other side. Using the first circle as a guide, cut through the retaining plies to the cord fabric, immediately above the sealant. Cut the plies at a 45-degree angle, with the knife blade pointing away from the center. Remove these plies separately from the cell wall.

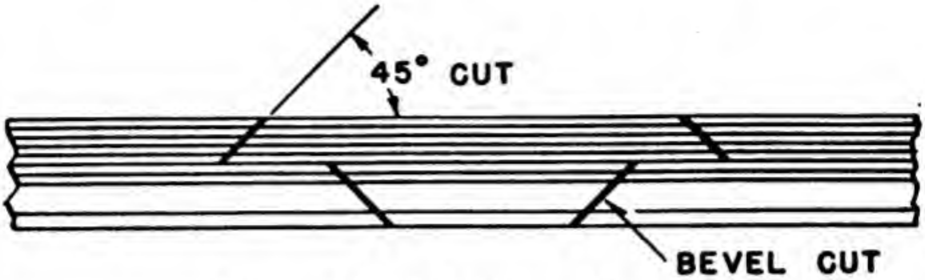


Figure 191.—Cutting out layers.

Locate the center on the exposed cord fabric and scribe two circles. Draw the first circle large enough to include all the damaged area, and the second circle with a radius 1 inch larger than the first circle.

Now draw a circle on the inner liner large enough to overlap the damaged area by 2½ inches. This area is your buffing surface, and it should be buffed before any section of the cell wall is cut away.

Using the first circle on the exposed cord fabric as a guide line, cut out the section—holding the knife at a 90-degree angle to the cell wall. After cutting out the section bevel, cut the edge of the hole in the same manner as you did the standard cell.

Buff the skived area and the exposed cord fabric lightly, as well as the exterior surface marked by the circle.

Build a trestle, and apply the sealant build-up in the skived hole—using the same methods as for the standard cell. Allow sealant to dry for a few hours before completing the repair.

After the sealant material you have already applied dries, skive off the excess sealant and apply a layer of cord fabric over the sealant. Complete the build-up

with sealant patches until it is flush with the outside surface.

Apply two outside patches over the sealant and the buffed area—the first patch overlapping the sealant by $2\frac{1}{2}$ inches, and the second patch overlapping the first by 1 inch.

Now you are ready to remove the inside support and apply the two inside patches. The first inside patch should overlap the hole by 1 inch; and the second patch should overlap the first one by 1 inch.

When all repair work is finished, place the support back under the inside patches and apply a weight of approximately 25 pounds on the repaired area. Then allow the repair to cure.

BLISTER REPAIR

When air is trapped between the liner and the nylon of a fuel cell, it causes what is known as an inner liner

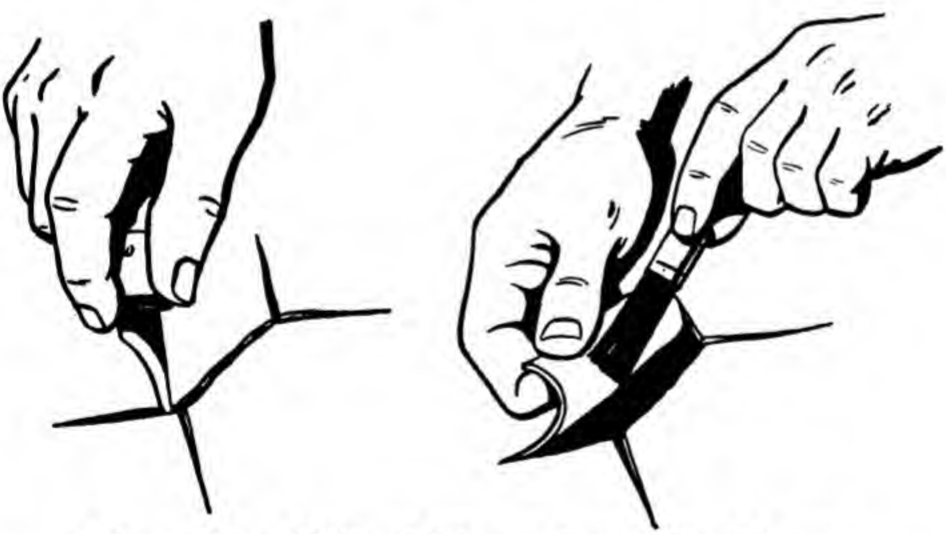


Figure 192.—Slitting blister, and cementing blister.

blister. This is often mistaken for ply separation, or loss of adhesion between layers. Don't be fooled.

Prepare the cell for a blister repair in the same way that you prepared the cell for a slit-type injury repair.

When the cell has been prepared, buff the liner sur-

face 2½ inches beyond the edges of the injury in all directions.

Slit the blister, as shown in figure 192, with a knife (from end to end), and buff the under side of the loose edges. BE CAREFUL not to damage the cell wall under the blister with the point of the knife. The slit made in the liner should resemble two Y's placed end to end.

After you have buffed the under side of the loose edges, apply two coats of cement to the inside surfaces, allowing proper drying time between coats. When the second coat of cement is tacky, stitch down the loose edges of the blister, making sure there is no air trapped underneath.

After the blister has dried thoroughly, apply a patch extending 2 inches in all directions from its edges. Then complete the repair in the same way that you would apply an inside patch to a slit-type injury.

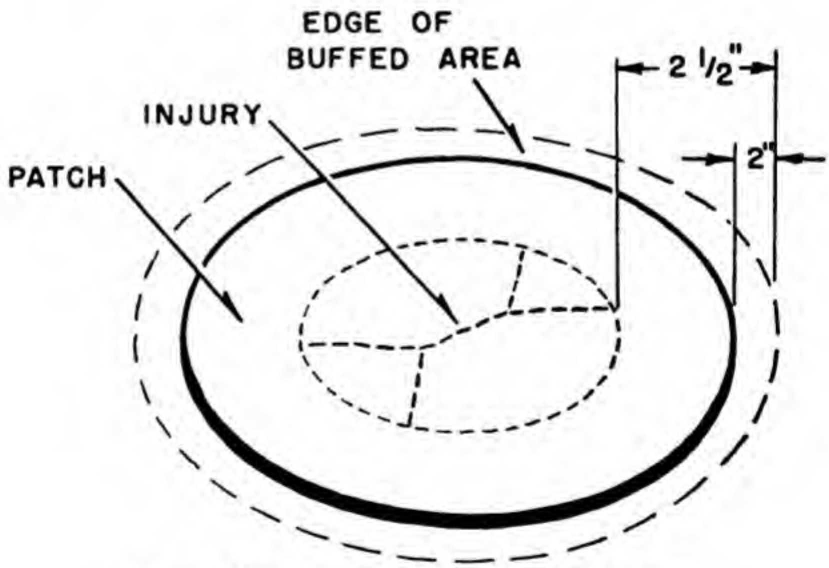


Figure 193.—Completed blister repair.

SEAM OR LAP REPAIR

Loose seam laps on the inside of the cell should be repaired as soon as they are noticed, or the separation will spread to the sealant.

Prepare the cell as you would for a slit-type injury.

Buff both surfaces under the loose lap. Then buff an area on top of the loose seam, extending this area 2½ inches in all directions from the edges of the separation.

When you have done that, wash the buffed surfaces lightly with a rag dipped in solvent to remove the buffing dust, and allow to dry.

Apply two coats of cement to the surfaces under the

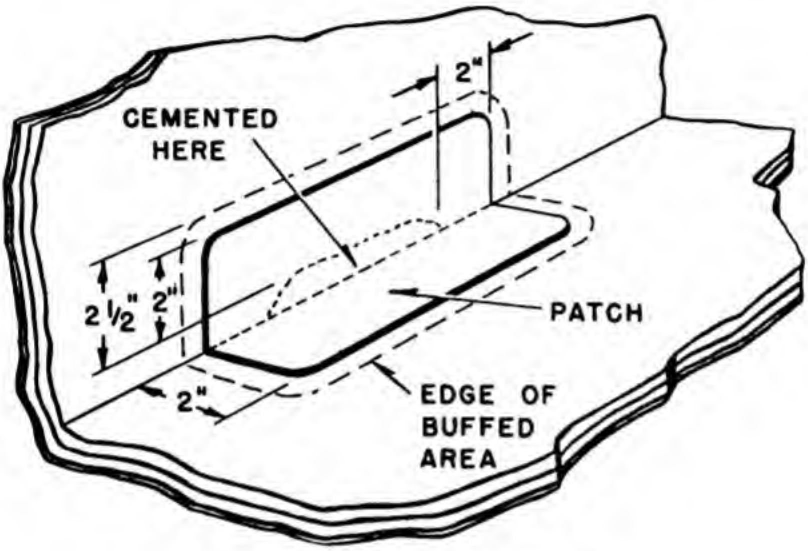


Figure 194.—Seam repair.

lap. Before you apply the second coat, make sure the first coat is thoroughly dry. While the second coat is still tacky, stitch the loose flap down firmly to remove all trapped air.

While the lap is drying, cut a patch of inside repair gum 2 inches larger in all directions than the separation. Round the corners slightly, and buff one side of the patch. Bevel the edges of the patch on the side opposite the buffed surface, and wash the buffed surface of both the cell and the patch lightly with solvent.

Apply the patch, and complete the repair as you would in applying an inside patch for a slit injury. Figure 194 shows you how the finished patch should look.

OUTSIDE LAP SEAM REPAIR

You can repair lap seams on the outside of a fuel cell WITHOUT the application of a patch.

Buff, wash and cement the inside surfaces of the loose lap. After allowing the repair to dry, stitch the lap down to remove trapped air, and paint the outside area with two coats of cement.

CORNER REPAIRS

Injuries to the corners of fuel cells are more difficult to repair than injuries on flat surfaces. In such cases

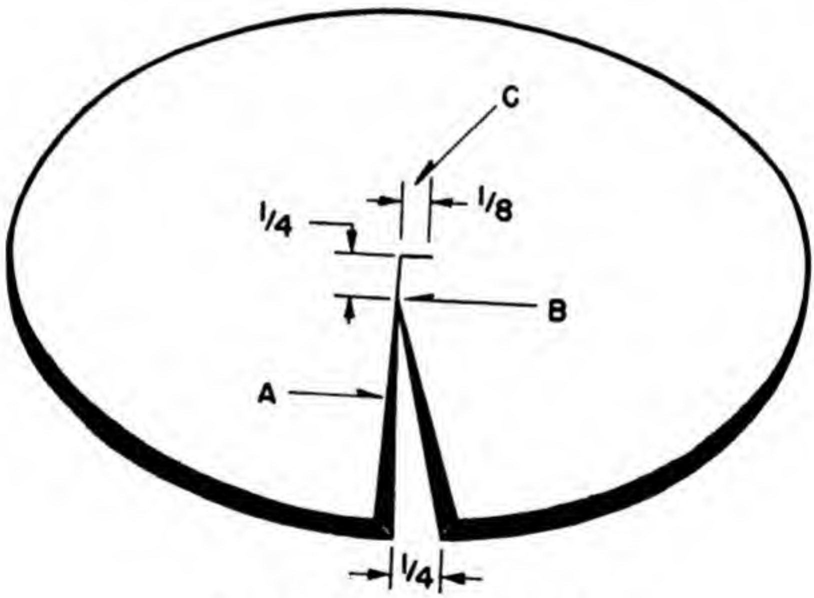


Figure 195.—Corner patch.

a specific method must be followed. Remember, do not attempt to repair any corner injury over 2 inches in length.

To make an inside corner repair, buff the inner liner around the injury for a distance of 2½ inches in all directions, and then buff the outside retainer for a distance of 3 inches in all directions from the edges of the injury. After buffing, wash the buffed surface lightly with solvent.

Cut two patches of inside repair material—the first patch extending 1 inch in all directions from the injury, and the second patch overlapping the first by 1 inch.

Buff both sides of the first patch and one side of the second. Bevel and feather the edges.

Holding the knife at a 45-degree angle, make a radius cut in each patch running from the edge to the center (*A*). At the end of the cut (in the center of the patch) make a slit to the right, ⅛ inch in length (*C*). Now make a 45-degree bevel cut—starting ¼ inch from the center (*B*) and extending it to the edge of the patch—¼ inch from the original cut. Take a good look at figure 195 before you start cutting.

Dry-fit the patch carefully into the corner. Be sure to place the slit so that the lap formed will be on a FLAT side, and as far away from the injury as possible.

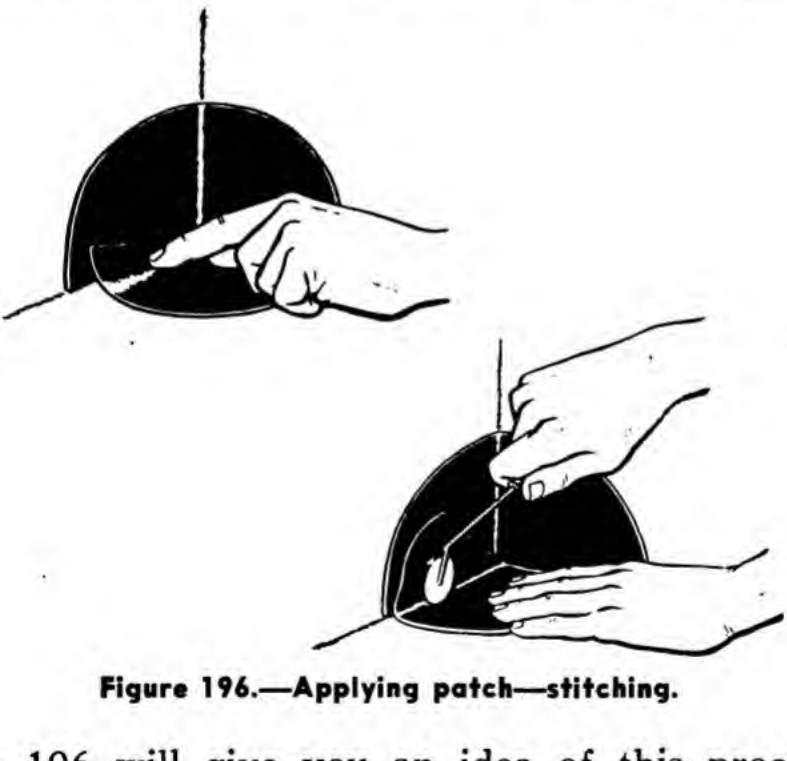


Figure 196.—Applying patch—stitching.

Figure 196 will give you an idea of this procedure. When you have fitted the patch, mark its outline on the inner liner so that you can return it to the same position when cementing.

Apply two coats of cement to the inner liner and first patch. While the cement is drying, cut a piece of

Holland cloth the same size as the second patch. Cut a ½-inch hole from the center, and place the cloth on the tacky side of the patch, leaving part of the radius edge exposed.

Stitch down the exposed radius edge on the inner liner and continue until you have reached the edge of the lap. Then apply cement to the part of the patch that the overlap will cover, and stitch it down as shown in figure 196.

Apply the second patch in the same way as you did the first—making certain that the overlap is opposite the overlap of the first patch, and that both surfaces forming the overlap have been buffed before cementing.

OUTSIDE CORNER REPAIRS

Outside corner repairs are made in much the same way as inside corner repairs—with a radius cut in each

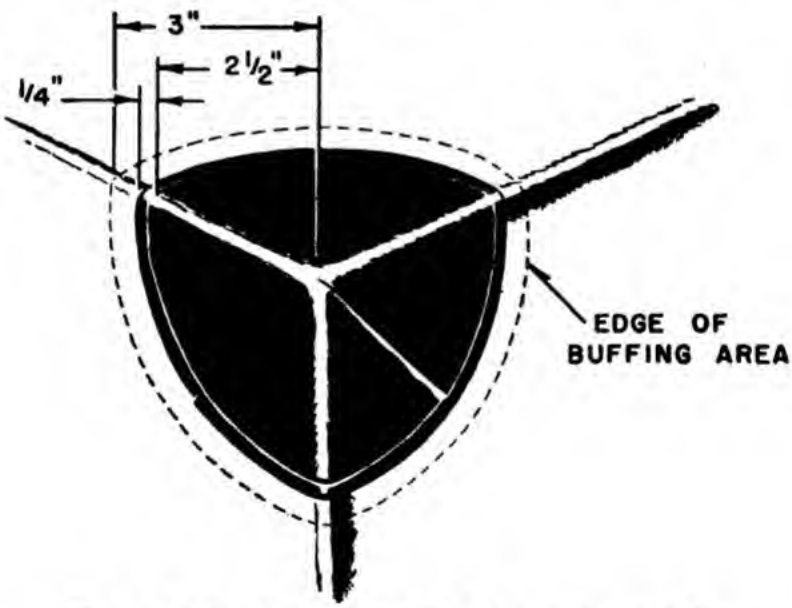


Figure 197.—Complete outside corner repair.

patch so that it will fit the corner. The buffing area should extend at least 3 inches beyond the injury in all directions.

Cut the first outside patch 2½ inches beyond the

injury, and apply so that the lap falls on one of the flat surfaces.

Cut the second patch ½ inch smaller in diameter than the first. The second patch is more or less protective; if necessary, build up the corner under it.

Apply the second patch as you did the first. When you're through with the repair, cover the entire area with two coats of cement.

Allow the repair to air-cure for 72 hours before reinstalling the cell. Figure 197 shows a corner patch completed.

FITTING REPLACEMENT

When you find that cell fittings have been injured—or have deteriorated—the cell should be removed from the plane immediately, and the fitting replaced or another cell installed.

Fitting replacement is not a difficult operation, but it takes time, patience, and great care. Replacement should be made only by experienced repair men.

The materials and tools required are the same as those used for other fuel cell repairs.

REMOVAL, INSPECTION AND INSTALLATION

In most cases it is necessary to remove the cell from the airplane in order to inspect it and to make repairs.

To remove the cell, follow these steps—

- Drain all the gas from the cell.
- Remove all inspection doors and hand hole covers, so that all parts are accessible.
- Disconnect all hose, tubes, and wire fittings.
- Next, collapse the cell by pulling in on the larger surfaces. Then place straps around the cell to hold it in the collapsed position, as shown in figure 198.

Remove the cell with as little distortion as possible.

Jostle the cell to facilitate its removal, and never leave the cell collapsed after removing it from the plane.

Mark the injury with chalk or powder—if the in-

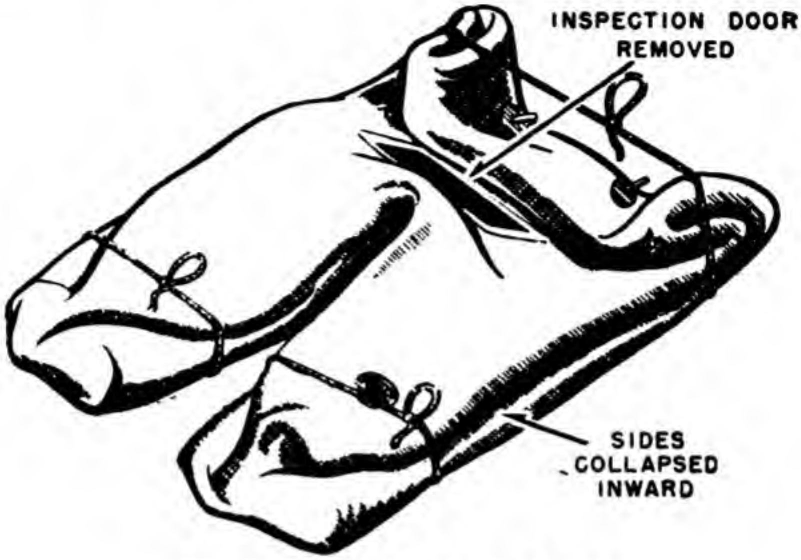


Figure 198.—A collapsed cell.

jury is visible. Gather all small parts and screws and place them in separate containers for each fitting. Keep all parts of the cell together so that they will not be lost.

HOW TO INSPECT THE CELL

In making an inspection of the cell, check it first for the presence of gasoline fumes. If fumes are present, air the cell for 24 hours before repairs are started. Air may be forced through the cell to lessen the airing time.

Check the inner liner for blisters. Blisters which are not very large at sea level may expand considerably at high altitudes because of change of pressure. Blisters may also be caused by bullets or shrapnel lodging in the cell wall.

Check the seams and corners for any edges that may have become loose. The surging of the fuel will cause the loose edges to separate further. Inspect the baffles

for cracks or loose edges. Check the flapper valves to see that they are in working condition and not stuck.

Check the various fittings for damage. Careless handling makes ADDITIONAL repairs necessary.

Check the outside cord fabric for deterioration from spilled fuel, and for worn spots which may have been caused by vibration.

Do NOT repair a sloshed cell. Replace it with one of

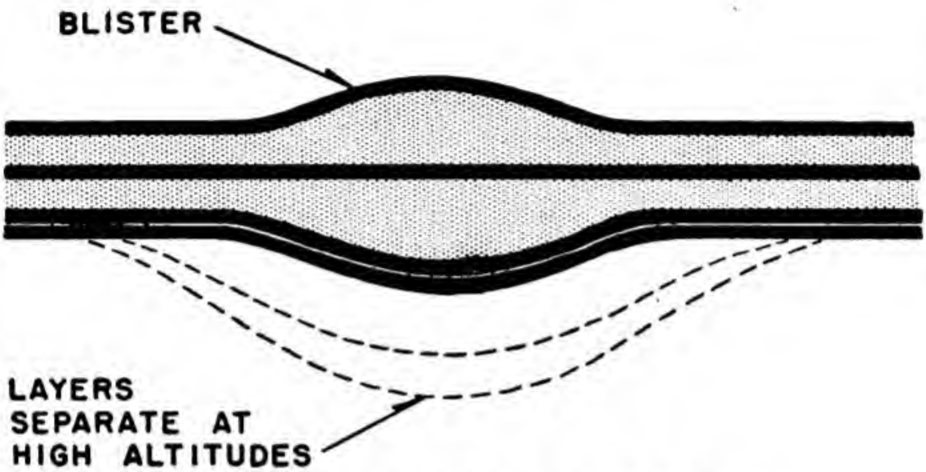


Figure 199.—Blister in the liner of a cell.

the new-type cells. After you have made your inspection, examine each injury thoroughly and determine the type of repair necessary.

INSTALLING THE CELL

Although the same general rules that apply to the removal of a cell also apply to its installation, there are other precautions to be observed—

Be sure the cell is the correct one for the cavity or shell. Cells are stenciled with the plane type, cell construction, and the location in the plane.

Determine if the cell is facing in the right direction. Inspect the shell or cavity for any foreign matter, such as bolts, nuts, rivets, etc. Insert the cell with as little distortion as possible. Jostle the cell into position whenever it is practicable. To aid in installation, dust the

outside of the cell with soapstone or talc. Do NOT use grease, oil, or any material that will cause deterioration.

Connect all lines and fittings to the cell. Inspect for injuries and wrong size clamps. Fill the cell with fuel, and inspect all places where there is a possibility of a leak.

GENERAL PRECAUTIONS

All of the following precautions should be carefully observed if you are to prevent damage to the cell while it's in storage or service.

Do not bend cell at fittings.

Never pick up a cell by the fittings or exterior tubes.

Do not force hose or fittings into place.

Carry a cell. Do not drag it.

Do not carry sharp instruments in your pockets while working in cells.

Always work in pairs in cells.

Remove shoes when working IN cells.

Always provide for proper ventilation.

Store cells in a clean, cool, dark, dry place—preferably in the original shipping container.

Store cells on their widest flat surface.

Seal all openings when storing.

Uncrated cells should never be stacked. If cells are in cartons, they may be stacked, but not so high as to cause the bottom carton to collapse.

CHAPTER 7

TUBING

LIFELINES

All tubing used in modern aircraft may be classified as either STRUCTURAL or NON-STRUCTURAL TUBING. Structural tubing is that used to carry loads, such as frames, struts, and landing gear. Non-structural tubing, with which this chapter is principally concerned, is that used in the fuel lines, air lines, hydraulic lines, and similar parts of the airplane.

The hundreds of feet of NON-STRUCTURAL TUBING found in aircraft today may be compared with your arteries and veins. They are the lifelines of the airplane. Destroy or damage the fuel lines, for example, and the entire airplane is put out of commission. It is needless to stress the great care which must be taken when you are working on these "lifelines," since you are already aware of the vital importance of maintaining the integrity of such strategic parts of the aircraft.

Tubing carries the gasoline and oil for the engine

and the hydraulic pressure for the control of flaps, landing gear, etc. Tubing is also used as a shield for electric wiring.

There are two types of metal aircraft tubing—rigid and flexible. RIGID tubing is used to carry fuel, oil, or hydraulic fluid. FLEXIBLE tubing is used to join low pressure lines and to make connections from fuel and oil lines to the engine itself.

Any fuel line DIRECTLY CONNECTED to the engine must be fastened by means of a FLEXIBLE joint to lessen the danger that engine vibration will make the line become brittle at that point. For these flexible joints, specially constructed flexible metal tubing or rubber tubing is used.

The rubber may be either natural or synthetic. Synthetic rubber is used wherever gasoline and oil resistant qualities are necessary. (Ordinary rubber deteriorates rapidly when it is exposed to gasoline or oil.)

In some metallic flexible tubing, rubber is combined with metal.

Flexible tubing is measured by the INSIDE DIAMETER, because in many cases it must fit over rigid tubing. It can be obtained in various wall thicknesses, and the size needed depends upon the job it is required to perform. Rubber tubing sizes are not held to as close a tolerance as rigid tubing. Its wall thickness will be only approximate.

The size of round rigid tubing is given in two dimensions — the exact OUTSIDE DIAMETER and the WALL THICKNESS. The diameter is given in fractions of an inch and the wall thickness in thousandths of an inch.

The accepted practice is to refer to tubing size by number, the number being the outside diameter in sixteenths of an inch—No. 2 being ⅛ inch, No. 3 being $\frac{3}{16}$ inch, No. 4 being ¼ inch, and so forth.

Aircraft fuel lines are made from aluminum, aluminum alloys, copper brass, or one of various plastics. The most widely used tubing material in modern airplanes is aluminum and its alloys.

Navy specifications require that the alloy and temper of tubing be marked by these identification bands every three to five feet. But certain sizes of tubing are sometimes stenciled with the tube material and condition of heat treatment, the information being marked in a line along the length of the tubing. While identification bands are used to indicate the aluminum alloy of which the tubing is made, they DO NOT tell you the particular use for which a tubing line installed in an airplane is employed. There are other markings which indicate the uses of the various lines. Don't confuse the two.

ALUMINUM TUBING

ALLOY	COLOR
2S	White
3S	Green
17S	Yellow
24S	Red
52S	Purple
53S	Black
61S	Blue

Aluminum alloy 52S tubing has the greatest number of uses in an airplane. Alloys 2S and 3S are used for parts where strength is not important, as in air speed indicator lines.

Aluminum alloys have taken the place of copper in tubing lines to a great extent because of their lightness and because they DON'T WORK-HARDEN or crystallize as rapidly as copper. Aluminum in the "so" condition may be fabricated and then installed in the airplane, but copper must be ANNEALED after fabrication and before it is installed. What's more, it must be re-annealed periodically to relieve the strain-hardening caused by vibration.

Copper tubing has now only one major use on an airplane—for small lines running from the engine to

various instrument installations and for the smaller lines of the hydraulic systems. It is used here, because it can be easily soldered. Soldered connections are desirable on instrument lines, because fittings are hard to install on such small tubes. In addition, soldered connections make it easier to dismantle and reassemble these small tubes without damaging the tubing or any fittings which may be present.

Brass is also used for aircraft tubing but, like copper, its use is limited. Some oxygen lines and parts of some flexible lines are made of it.

REPAIRING TUBING

There are two types of tubing repairs. One is the COMPLETE REPLACEMENT of the injured tubing. This should always be done when time and the facilities permit.

The other type of tubing repair is the INSERT TYPE. This is a temporary repair, and should be replaced with a complete new installation as soon as conditions permit you to do so.

Repairs to tubing depend, of course, on the type and use of the damaged tubing. With most tubing, you will have to perform the following steps.

Make a TEMPLATE to determine the approximate length of the tubing and the path it must follow.

Cut the tubing to approximate length and remove the burrs.

Bend the tubing to shape.

Fit to the job, and cut to exact length.

Attach the fitting.

Flare the tubing if the flared type of fitting is used.

Install the completed section of tubing.

In most of your repair jobs, you'll find yourself bending and fitting fuel lines on the job WITHOUT an accurate drawing of the original pieces. The chief objective is to follow the same path as the original piece and make

sure that the replacement lines up with the fittings to which the tubing is to be attached.

One way you can figure out the path the tubing is to follow, and its approximate length, is to MAKE A TEMPLATE of iron wire (approximately #10 gage). If you don't have such material available, you can use discarded tubing ¼ inch in diameter or less. You can also use as a guide the old tubing which is to be replaced.

BEFORE BENDING, you cut the repair tubing to its APPROXIMATE LENGTH. Only AFTER it has been bent and checked for alinement with the fitting to which it will be attached, do you cut it to its EXACT length.

Figure 200.—Cutting tubing with a tube cutter.

Tubing must be cut exactly square and it must be perfectly burred if the steps which follow are to turn out right. There are two ways to cut tubing.

One way is to use a regular TUBE CUTTER which looks like a pocket-size pipe cutter and which automatically makes a square cut. The other way is to use an ordinary hacksaw. If you use a hacksaw, pay particular attention to the way you hold the tubing and to the type of blade you use to make the cut. Figure 200 shows a tube cutter, and 201 a VEE-block which is used to hold the tubing when it is cut with a hacksaw. Hacksaw blades for cutting tubing should have 32 teeth to the inch.

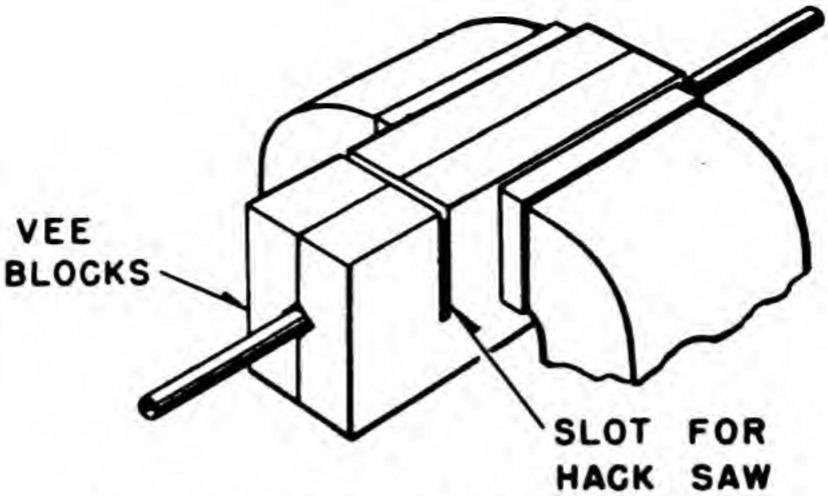


Figure 201.—Vee blocks for holding tubing.

After the end of the cut tubing has been FILED SQUARE as in figure 202, it must be burred inside and out, otherwise you will have a leaky joint or a split tube. Inside burrs can be removed with a machinist's scraper or a pocket knife as in (*A*) of figure 203. Outside burrs can be removed easily with a flat file as in (*B*). Don't round the corners excessively.

Next, clean out any foreign particles from the inside of the tube—such as filings, chips, burrs, and grit. This cleaning will help to prevent split flares and pock marks on the fitting seats. If you have it handy, compressed

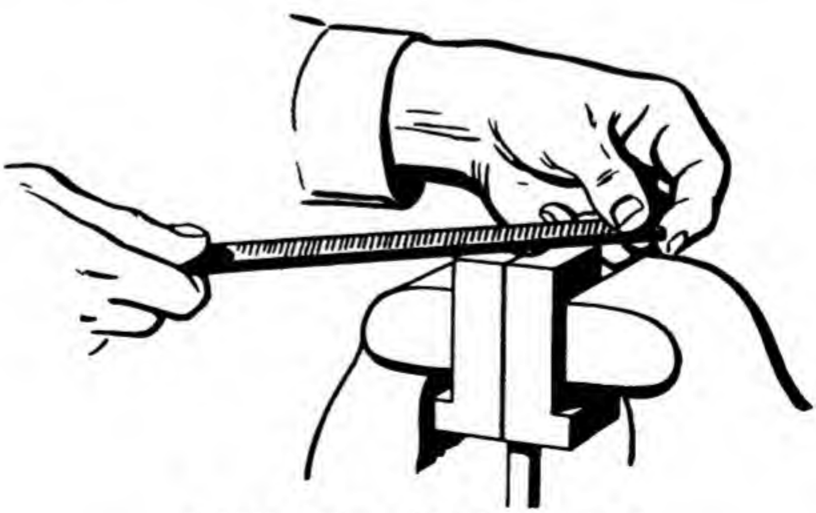


Figure 202.—Filing tubing ends.

air blown through the tube is the best way to clean out these particles. If you must file and burr a tube after it is partly installed, it is a good idea to stuff a rag part way into the tube to prevent chips and filings from dropping in. Then carefully remove the rag when you have finished. Another way to clean out the inside of the tubing is to use a long, thin brush.

(A)

(B)

Figure 203.—Burring inside and outside.

Now take a quick check to be sure the tubing is round, cut squarely, and that it is clean, and free of draw marks, mill scale or scratches. This inspection is particularly important if the end of the tubing is to be flared to accommodate a flared type of fitting. Scratches and draw marks are apt to spread and split the tube while it is being flared, especially if it is made of aluminum. Scratches in the tube may be removed by burnishing, if the scratches are no deeper than 10 percent of the thickness of the tube wall.

TABLE XIII—BEND RADII OF AIRCRAFT ALLOY TUBING

TUBE MATERIAL	OUT-SIDE DIA. (Inch) Incl.	WALL THICK-NESS (Inch) Incl.	MINIMUM BEND RADIUS O.D. x Factor Below		METHOD OF BENDING (See legend below)					HEAT TREATMENT	
						FILL WITH					
					NO FILL-ING	SAND		RESIN	Spec. 11078 or other Low Temp Fusing Alloy	BEFORE BENDING	AFTER BENDING
			Struc-tural Use	Piping Fluids		Coarse	Fine				
Aluminum and 52 Aluminum Alloy	0.25 1.50	.032 .051		3	#3		#1 or #2		#4 or #5 #1 or #2		
	1.625 3.000	.057		3			#1 or #2				
17 and 24 Aluminum Alloy	0.25 2.00	.022 .065	6	4	#3		#1 or #2		#4 or #5 #1 or #2	Anneal or Ht. Treat	Heat Treat
	2.25 3.75	.065 .120	6	4			#1 or #2			Anneal or Ht. Treat	Heat Treat
Brass			5	4	#3			#1 or #2	#1 or #2		Anneal
Copper	0.125 1.125	.035 .049	3	3	#3		#1 or #2	#1 or #2			Anneal
Copper, Silicon, Bronze			3	3	#3		#1 or #2	#1 or #2			Anneal
1025 Steel	0.125 1.50	.028 .065	5	3	#5	#6				Torch	Normalize
	1.625 4.000	.065	5	3		#6				Torch	Normalize
X-4130 Steel	0.188 1.500	.022 .065	5	3	#5	#6				Torch	As Required
	1.625 2.750	.049 .120	5	3		#6				Torch	As Required
Corrosion Resistant Steel	Minimum Bend Radius depends on Composition, Condition and Bending Equipment.								#2		Anneal

LEGEND—METHODS OF BENDING

#1 Cold Bending (hand)
#2 Cold Bending with machine (using filler)
#3 Cold Bending with machine (internal mandrel)
#4 Cold Bending with die press (with or without filler)
#5 Cold Bending with rolls (with or without filler)
#6 Hot Bending (hand)

Burnishing is done by running a hard, smooth tool over the affected part of the tube. This forces the surrounding metal toward the scratch, filling it up and also redistributing the strength of the tubing at the point of the scratch. If scratches are not removed, vibrations and stresses centered in the scratches will eventually cause a crack and a leak.

Occasionally, dents will be found in tubing. These can also be removed (if they are less than 20 percent of the tube diameter) by running a die or bullet-like tool through the tube. Figure 204 shows a tool for removing dents.

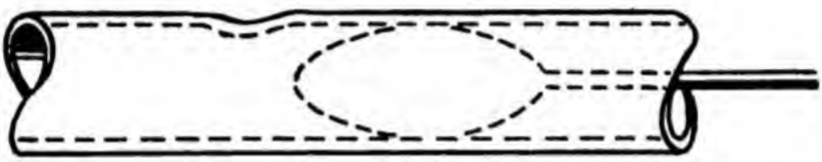


Figure 204.—Removing dent.

When aluminum tubes are to be anodized for greater resistance to corrosion, it is best to wait and treat the tube after all flaring and bending has been completed.

BENDING TUBING

After the tubing is cut, it is ready to be bent to the shape of the template. You can do this bending by hand with a wire tube bender, in Vee-blocks, with a mechanical hand tool bender, over a radius block, or in a production bending machine.

THE TUBING MUST BE SHAPED SO THAT IT IS NEITHER BUCKLED NOR FLATTENED.

Table XI gives you the bend radius of the various kinds of aluminum alloy tubing.

Small sizes of tubing up to $\frac{1}{4}$ inch can be BENT BY HAND if the curve is bent gradually. In hand bending, the radius must be GREATER than is necessary when you use a mechanical bender, to avoid buckling or flattening the tubing.

Almost any size of tubing can be bent with the Vee blocks shown in figure 201. (Tubing ½ inch in diameter or more, however, must be bent with the aid of FILLER MATERIAL.) To use the Vee blocks, clamp them in the vise with the tubing between them and bend the tubing by hand. This method of holding the tubing is exactly the same as that used when you are cutting it with a hacksaw.

HAND TUBE BENDERS like those in figure 205, may be

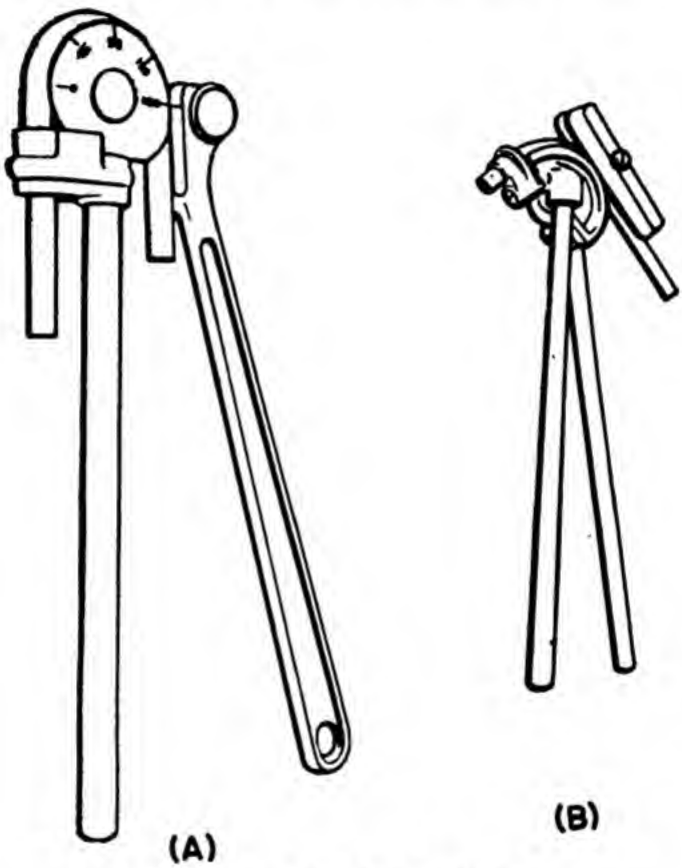


Figure 205.—Hand tube benders.

used to bend the smaller sizes of tubing. Each size of tubing requires a different size of bender. The bender has three parts—a radius block, a clamp and a forming bar.

To start bending with a hand bender, insert the tube in the bender and clamp the tube in place. Then, place the mark in the forming bar opposite the 0-degree mark on the radius block and begin bending.

Be careful in bending tubing with it to see that the tubing does not slip in the clamp. The clamp fits rather loosely on most hand tube benders. One way to avoid slipping is to wrap a piece of emery cloth around the tubing underneath the clamp. The larger sizes of tubing will require the use of filler materials to prevent wrinkling or buckling.

Bending with RADIUS BLOCKS is a common method of bending tubing. Figure 206 shows a radius block.

The radius of the bend should be carried about 15 degrees past the desired bend angle to allow for the tube's springback. Cut a groove to fit the tubing in the block. To hold the tubing in place, use a small clamping block which is also grooved to fit the tubing. Sizes of tubing larger than ½ inch in diameter requires the use of filler material.

Figure 206.—Radius block.

The production tube bender is used in A. and R. maintenance shops where a considerable amount of tubing is bent. Instead of filler material, a mandrel is used inside the tubing to avoid distortion as it is being bent.

THE FILLER

The larger sizes of tubing MUST BE FILLED with some material to prevent flattening the outside and buckling the inside during bending. Filler materials which are commonly used include sand, resin, and special bending alloys with a very low melting point.

SAND is the most commonly used filler. For best results, it should be fine and dry. To fill the tubing, plug one end tightly with a piece of soft wood. If the tubing has been cut with enough extra material, you can plug one end by flattening it and bending it over as in figure 207.

As you pour the sand in through a funnel, tap the tubing with a stick to make sure that the sand packs firmly into place. Then when the tubing has been tightly packed, plug up the other end. Be sure the sand is in there firmly, because its purpose is to support the walls of the tube.

For larger sizes of aluminum alloy and copper tubing, SPECIAL ALLOYS are used as fillers, because they

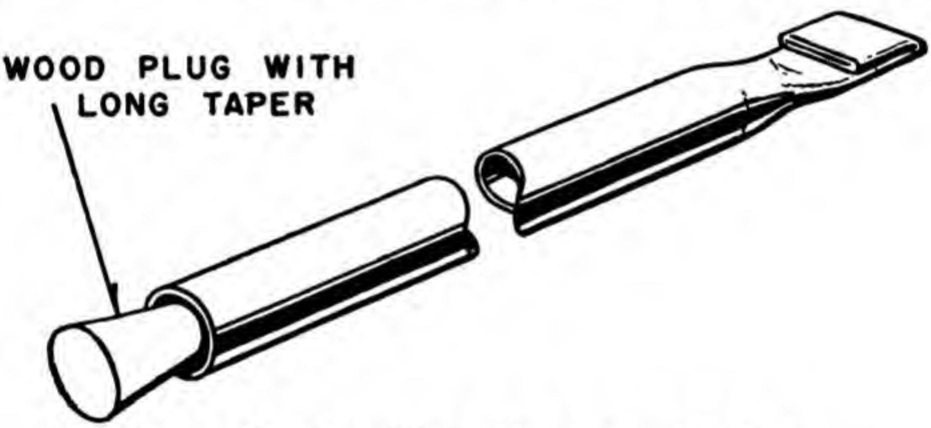


Figure 207.—Repairing tubing to receive filler.

expand upon cooling and thus fill the tube efficiently. They are especially useful for complicated bends.

The trade names for some of these fillers are Cerrobend, Bendalloy and Tuballoy. Although they are more expensive than sand or resin, they can be used over and over, practically indefinitely, if they are heated properly. NEVER heat them with a torch or an open flame because it is likely to ruin them. For best results these alloys should be heated in a ladle in boiling water. They melt easily in boiling water because their approximate melting point is 150° F. When using them with copper tubing, you should protect the tubing from possible tinning of the inside by a light coat of oil.

This is the way you use them. After one end of the tubing is plugged, fill the tube with boiling water to preheat it. Preheating guarantees that the filler alloy will remain liquid until it has filled the tubing. When the tubing is full of boiling water, pour in melted filler alloy until all of the water is displaced.

Now, with your tubing full of the alloy, hold it under cold running water to chill the filler. Be sure that the filler alloy is fully cooled before you attempt to bend the tubing. The alloy bends easily when it is cold, but has a tendency to break when warm. The alloy may also break if you bend the tubing too rapidly, so GO SLOW.

Such alloy-filled tubing may be bent with the aid of any of the bending apparatus just described. When the bending is completed, remove the alloy by heating the tube in steam or boiling water.

ANNEAL IT

Both copper and aluminum alloy tubing must be in the DEAD SOFT CONDITION before they are bent. While they will usually be in that condition when you receive them, you will sometimes find that the tubing will prove too hard to bend and must be annealed. Copper MUST ALWAYS be annealed AFTER bending, before it is installed.

Your big problem in shop annealing will be that of deciding WHEN the annealing temperature has been reached. If you're working an aluminum alloy, heat it with a gasoline blow torch or a welding torch until it will char a soft wood splinter which is touched to it. Another check for temperature is to apply a coating of carbon with a carburizing flame of the welding torch. Then adjust the flame to neutral, and burn off all the carbon.

Copper must be heated to a temperature of approximately 1000° F. When it is at this temperature, it will glow red in a dimly lighted room. Rainbow colors ap-

pearing on the copper will indicate that the temperature is nearly correct.

After annealing, aluminum tubing should be allowed to cool in air. Copper lines, however, should be quenched in water—BUT ONLY if a tank is available large enough to allow quenching of the whole section of tubing. Brass should be cooled in air.

LAYING OUT TUBE LINES

You must avoid laying out tubes from point to point, in a straight line. It is almost impossible, if the tube is laid out in a straight line, to flare the tubing (enlarge the end) to the exact length and prevent the flare from being PULLED OUT when the fitting is tightened. Then

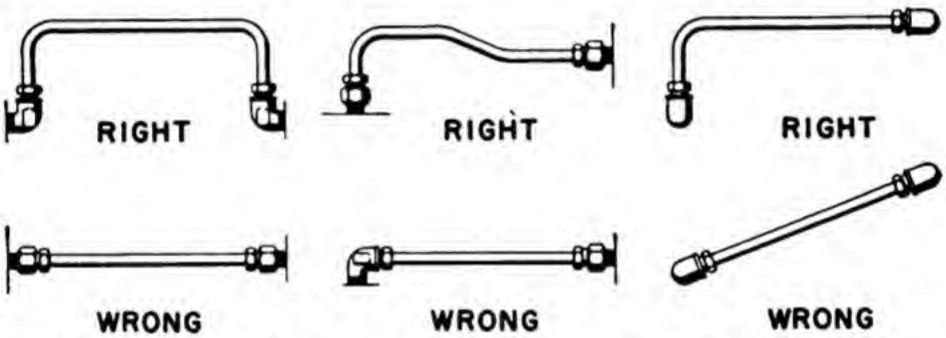


Figure 208.—Right and wrong methods of installing tubing and fittings.

too, a straight tube provides no opportunity for expansion and contraction due to temperature changes. Figure 208 shows the right and wrong way to lay out tubing.

LOCATING THE BEND

Suppose that you have a piece of tubing which you want to connect by a flared fitting to another tube. Before you can make the bend there are two things you must know: The minimum BENDING RADIUS of the metal tubing to be bent, and the distance from the end of the tubing where the bend is to be located.

The BENDING RADIUS of metal tubing VARIES WITH

THE TYPE OF METAL FROM WHICH THE TUBE IS MADE. Steel tubing, for instance, cannot be bent as sharply as a tube of the same dimensions made of aluminum alloy. If you try, the steel tube will crack or break. Therefore, before you bend any tube, find out the smallest bending radius for that specific tube, and DO NOT make the bend ANY SMALLER. Check Table XIII for the bend radius of the various tubing materials.

Having figured the bending radius of your specific tube, you are ready now to determine the answer to the second question: How close to the end of the tube should you make the bend?

To avoid subsequent difficulties in FLARING the tube and in assembling the two tubes later, you must be sure to allow a sufficient length of straight tube, measured from the end of the tube to the start of the bend. Experience has taught that for a two-piece INSIDE thread fitting, the length of straight tubing from the end to

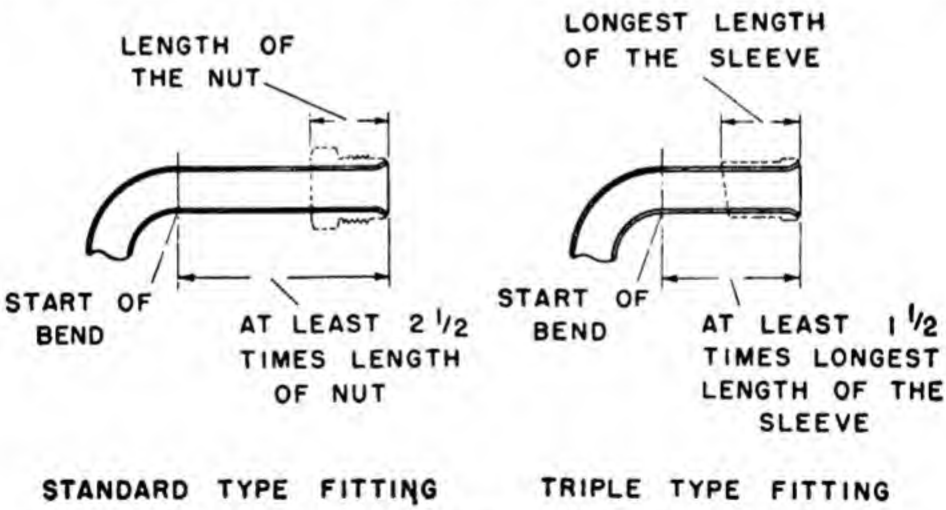


Figure 209.—Locating bends in tubes.

the start of the bend must be at least TWO AND ONE-HALF TIMES THE LENGTH OF THE COUPLING NUT.

For a three-piece OUTSIDE thread fitting, this space should be at least ONE AND ONE-HALF TIMES THE LENGTH OF THE SLEEVE. Figure 209 illustrates how to locate bends in tubes when standard or triple type fittings are used.

After you have located the bend, you can use any suitable method of those just described to bend the tubing. The next step is to ATTACH the tube fittings.

A tube fitting is a small metal part which is used to connect pieces of tubing to tanks, carburetors or to other pieces of tubings. These fittings come in many shapes, each designed for a particular function. Figure 210 shows several types of fittings.

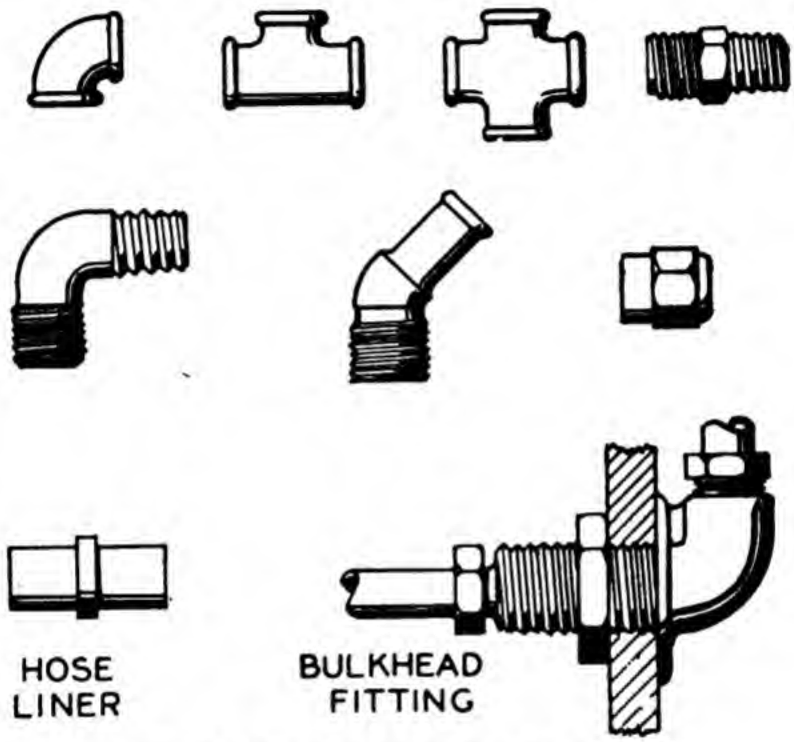


Figure 210.—Several types of fittings.

Fittings are attached to the tubing lines by SOLDERING OR FLARING. The flaring method is used mostly for fuel, oil, or hydraulic lines. Soldered connections are used on copper lines that must be taken apart and reassembled frequently. One form of flared fitting is the BULKHEAD FITTING shown in figure 210. It has four parts—a coupling which runs through the bulkhead, a nut to secure it, and two nuts to fasten the tube to the coupling.

There are two kinds of flared fittings—the standard two-part fitting and the triple tube fitting shown in

figure 211. The triple tube type is used where it is necessary to make connections in close quarters since the tubing extends a much shorter distance into the fitting and therefore may readily be removed. It is better for use in hydraulic systems, because it supports the tubes at the point of attachment.

A fitting will have two or more ends to which connections will be made. All of the ends may have pipe threads to make connections to carburetor, gas tank, accessory, or another fitting. Or, they may have machine threads to receive nuts for coupling.

The following table gives the outside diameter for

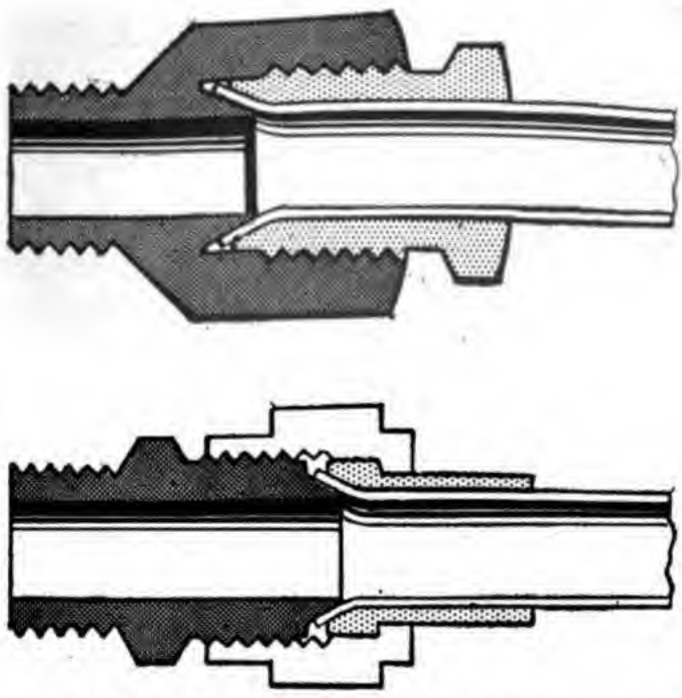


Figure 211.—Standard and triple tube fittings.

the common tubing sizes for fuel and oil lines and gives also the corresponding size of the tube fitting required. This table refers only to the pipe thread. The diameters of the sleeves and nuts must be such as to fit the tubing properly. In picking a machine thread fitting for a piece of tubing, choose one which matches the OUTSIDE diameter of the tubing. In choosing a pipe thread fit-

ting for a piece of tubing, choose one which matches the INSIDE diameter of the tubing.

TUBING SIZES

Tubing Diameter	Pipe Thread Size
1/8	1/8
3/16	1/8
1/4	1/8
5/16	1/8
3/8	1/4
1/2	3/8
5/8	1/2
3/4	3/4
7/8	3/4
1 —	1 —
1 1/4	1 —

FLARING

Place the nut and sleeve over the end of the tubing before you begin the flaring process, as they obviously will not slide on over the completed flare.

FLARING, or BELLING as it is sometimes called, is the STRETCHING OF THE END of the tubing to match the fitting which holds it in place. Figure 212 shows a piece

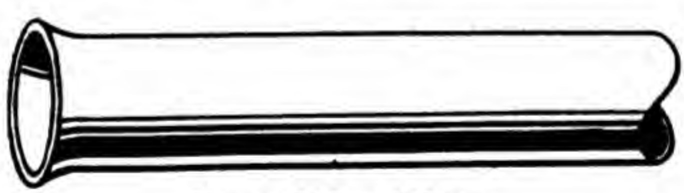


Figure 212.—A flare.

of tubing with a flared end. Flaring is usually a hand process. There are several flaring tools which you will use—the ball type, the hammer type, and the combination type.

The STANDARD TYPE of flaring tool is used for a two-piece fitting, while the TRIPLE BALL TYPE of flaring tool is used for a three-piece fitting. Both are recommended for thin-wall, standard weight, soft copper or aluminum

tube ONLY, with an outside diameter of 3/8 to 3/4 inch. The following instructions apply to both types.

Slip the B nut or the triple nut and sleeve over the end of the tube. It should protrude about 1/16 inch for a 1/2 inch outside diameter tube. For a larger or smaller tube, allow correspondingly more or less protrusion. The nut and tube are then gripped in a vise or held in the hand for flaring.

Insert the flaring tool to the tube shoulder and rotate, pressing outward and downward until the flare fits the nut. You will get the best results from a slow

(A) (B) (C)

Figure 213.—Ball type flaring tool.

circular wiping motion and a firm even pressure to hold the tool neck against the tube.

After flaring, thread the tool nut to the tube nut to even out the flare. When using the triple type flaring tool, screw the tube nut to the threaded portion of the tool. Excessive wrench pressure is not necessary to insure a smooth flare.

Figure 213 shows how a ball type flaring tool is used. Drawings (*A*) and (*B*) show the nut and sleeve being slipped over the end of the tube. Drawing (*C*) shows how the flaring tool spreads the end of the tubing.

The COMBINATION HAMMER TYPE of flaring tool is used on thin wall, soft annealed copper or aluminum tubing only, with outside diameters from 1/8 to 1/2 inch. It will flare tubing for either the two or three-piece fittings. This is the way it works—

Slide the flaring pin yoke as far back as it will go and spread the block jaws in order to insert the tube, as in figure 214. A spring catch keeps the flaring pin raised while you slide the yoke.

Figure 214.—Combination hammer type flaring tool.

The tube should be approximately flush with the top of the flaring block jaws. Slide the yoke over the tube

Figure 215.—Using a combination flaring tool.

and clamp it tightly in place with the adjusting screw as in (*A*) of figure 215.

Lower the flaring pin to the tube either by hand or by tapping it slightly with a hammer. Start the flare with light hammer blows, as in (*B*), and continue until

it is completed. To remove the tube, loosen the yoke and slide it back to its original position.

The STANDARD OR TRIPLE HAMMER TYPE flaring tools are designed for copper or aluminum tubing of moderately heavy wall thicknesses with outside wall diameters from 3/8 inch to 2 inches. The standard type is used on two-piece fittings and the triple type on either type.

Screw the tube nut and flaring tool together until only the last thread shows.

Insert the tube as far as it will go. Grasp the tube beneath the tool and flare it with a number of light hammer blows. The first few blows, especially, SHOULD NOT BE TOO HARD because the nut may become too tight in the tube.

After the flare has been well started, screw the nut and flaring tool tightly together. Then, grasp the

Figure 216.—Using standard or triple hammer flaring tool.

TOOL, rather than the tube, and flare until completed. With the standard tool, the progress of the flare can be observed through the cutaway. In the triple type tool you can't see how the flare is coming unless you unscrew the tool from the tube. If the flare is not completed, replace the tube and finish it.

Although incorrectly formed flares may SEEM to be satisfactory and pass initial pressure tests, THEY CANNOT BE DEPENDED UPON FOR CONTINUOUS SERVICE. To insure proper seating, all flares should conform to accepted general requirements and also to certain requirements which are determined by the type of fitting to be used for coupling the tube.

Correct diameter of flares for the standard and triple type fittings are illustrated in figure 217. Undersize and oversize flares are shown in figure 218.

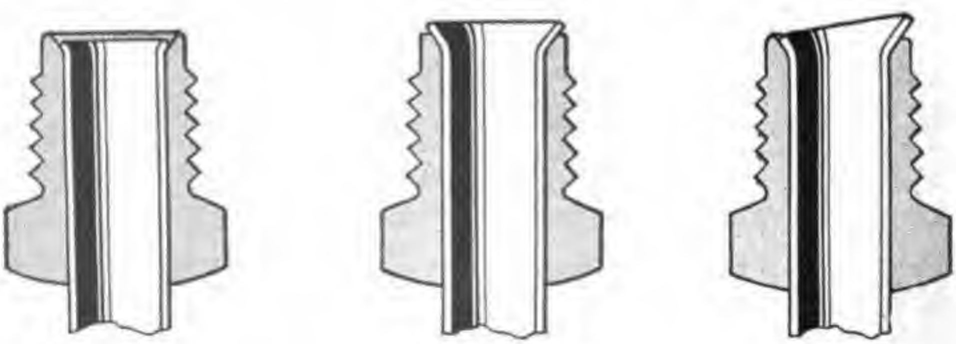
FLARE DIAMETER FOR STANDARD TYPE FITTINGS

FLARE DIAMETER FOR TRIPLE TYPE FITTINGS

Figure 217.—Correct diameter of flares for standard and triple type fittings.

For quickly checking flare diameter, gages are available which have holes for measuring go and no-go flare sizes. You see such a gage in figure 219.

Another thing you must watch is the flare angle of the tube. It should be the same as the flare angle of the fitting. Incomplete flares cannot be depended upon to



TOO SHORT TOO LONG UNEVEN

Figure 218.—Bad flares.

draw down on the fitting seats.

In such cases, the nut tends to climb up on the flare so that there is very little grip on the tube after the

fitting is assembled. So, DO A GOOD JOB. Complete all flares to the proper angle.

Flares MUST BE square and concentric with the tube and tube nut in order to seat properly. There are two reasons why a flare might be out of square and eccentric. Perhaps you did not cut the tube off square, or maybe you formed the flare unevenly, as in figure 245. Such flares are almost impossible to correct. They should be cut off and done over.

If the unevenness of the flare is due to careless use

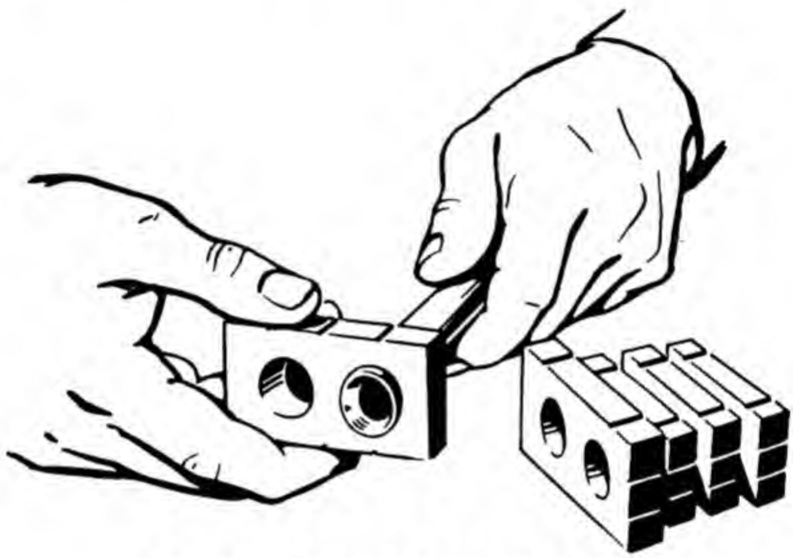


Figure 219.—Go and no-go gage.

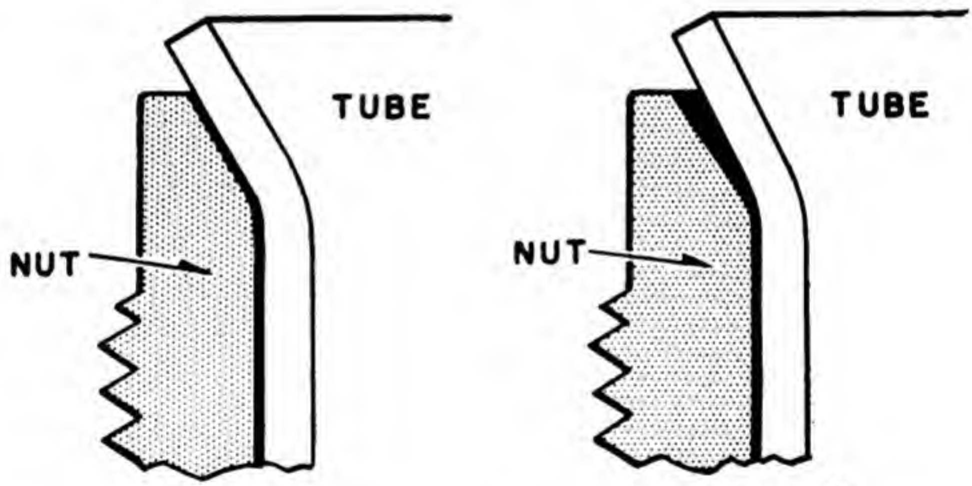
of the flaring tool, then usually the angle of flare is also faulty. Uneven flares are generally not alined with the fitting seats and for this reason require greater wrench pressure to draw them tight. If the flare is LARGE, the elongated side will bottom in the fitting to prevent normal seating. Or, it may stick in the fitting threads. If the flare is relatively SMALL, the shorter size will not be gripped securely between the fitting seats and leakage may develop.

The radius at the base of the flare should coincide with that on the tube nut, otherwise you may experience difficulty in getting a proper seat.

If the tube has been flared into the nut or sleeve of

the fitting, the radius will automatically be correct. Flaring blocks are originally provided with the correct radius. You will obtain this radius, IF correct flaring pins are used. Make-shift wooden flaring blocks quickly flatten out at this point and should not be used. Figure 220 (*A*) shows a good job of flaring in which the radius at the base of the flare coincides with that on the tube nut. Figure 220 (*B*) shows an incorrect flare. The thickness of the flare at its edge must not be less than 82 percent of the original wall thickness. If a flare has been drawn down by a fitting, it must retain 50 percent of its original wall thickness. Otherwise, the flare must be cut off and a new one made.

After the flare has been made, you should give it another inspection for surface markings. If you neglected to remove chips, filings, or burrs, before flaring they will have been pounded into the flare and will cause



(A) (B)

Figure 220.—Correct and incorrect radius.

pock marks. Pock marks, scratches, draw marks, or other surface irregularities, make tight sealing uncertain. You should guard against them as much as possible. If such marks are present, cut off the flare and reflare the tube.

A flare which has split lengthwise may be the result

of working on tubing which is too hard or of uneven texture. Split flares can also be caused by the opening up of surface scratches or draw marks.

ASSEMBLING THE CONNECTION

The first step is to make sure that a flare is in its perfect seating form. Flares on thin, soft annealed copper and aluminum tubes can usually be smoothed out to their proper form IN THE FITTING as the assembly progresses. With heavier and harder tubes, it is a

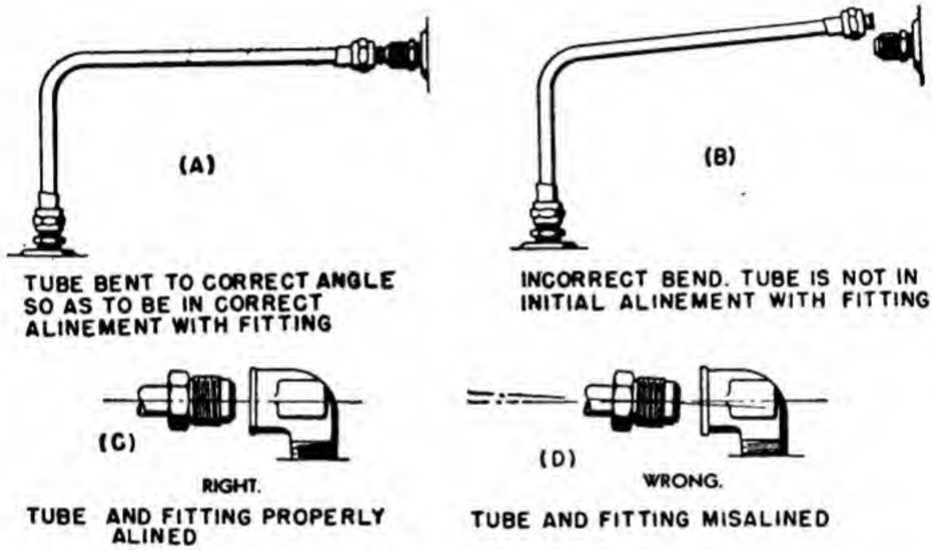


Figure 221.—Correct and incorrect alinement.

better idea to draw the flare into its perfect seating form by first assembling it with a hardened seating tool.

With the two-piece fitting, the nut should turn freely on the tube after it has been flared. If the nut sticks, free it up before assembling the joint by tapping it on the flats of the hex with a hammer.

With the three piece fitting, it is preferable to allow the sleeve to remain tight on the tube, provided it is properly in place against the flare. If the sleeve is tight, there is less chance for it to turn on the tube and wipe the flare surface.

A few drops of oil on the threads will help in assem-

bling the nut to the fitting. If the fitting parts are made of aluminum alloy, then the threads must be lubricated with a suitable anti-seize compound to prevent seizure.

WARNING—Do not use oil in assembling fittings on oxygen lines. Oil and oxygen produce an explosive mixture.

Before you assemble a joint, check to see that the tube is in proper alinement with the fitting, and that it DOES NOT HAVE TO BE SPRUNG into position because

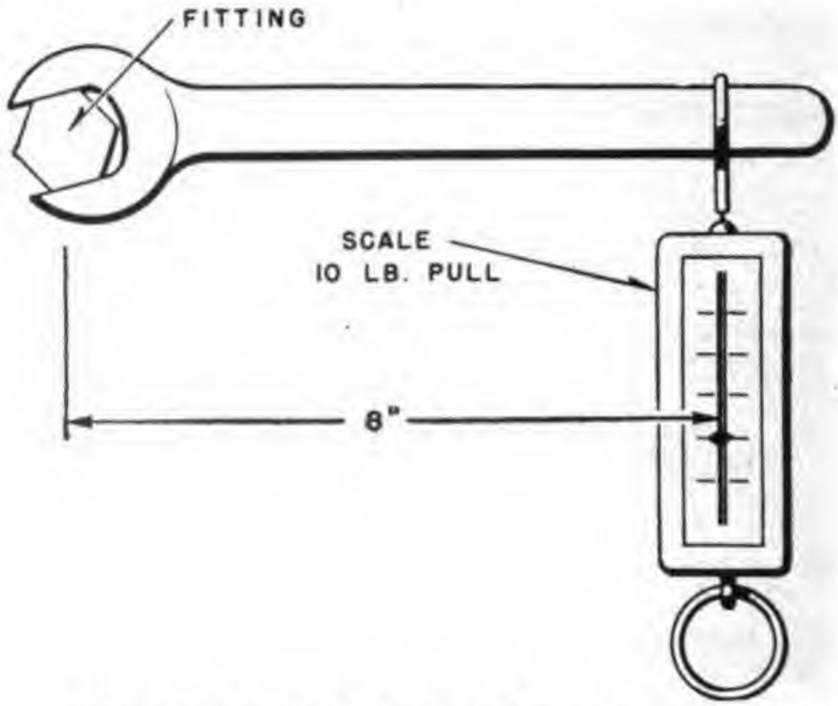


Figure 222.—How to estimate torque pressure.

of improper bending. Figure 221 shows right and wrong alinement of tubing and fitting.

When you get ready to tighten the nut, thread the parts together by hand as far as possible, then loosen the nut and jiggle the tube to be sure the flare is down on the seat.

If at all possible, use a torque wrench to secure the proper torque pressure on fittings. There is just as much danger in overtightening as in undertightening a fitting. If a torque wrench is not available, the device

shown in figure 222 can also be used to ascertain the correct torque pressure.

When you install tubing, be sure to support it adequately (at approximately 24-inch intervals) with standard clips or clamps, except when a support will

TABLE XIV

Allowable Make-Up Torque for Use with ANA Fittings

Tube O.D.	Wrench Torque (Pound—Inches) Aluminum Alloy Tubing	
Inches	Min.	Max.
1/8	....	....
3/16	....	....
1/4	40	60
5/16	60	80
3/8	75	125
1/2	150	250
5/8	200	350
3/4	300	500
1 and over	500	750

interfere with the proper performance of flexible connections. The installation should be designed and made to prevent injury or chafing of the tubing.

Also be careful to avoid having unsupported sections of fuel or oil lines of which the vibrating frequency will be such that tubing failure may result.

After the line has been assembled, it should be checked and tested to see if there are any leaks. Hydraulic lines, and others, should be filled with their particular fluid, and pressure applied if possible. On air pressure, oxygen, and vacuum lines, a soapy water solution is applied to fittings for testing.

Here are some of the most common causes of leaks—

Not enough wrench torque.

Too high wrench torque.

Flaring poor, cracked, rough or split.

Careless assembling.

Assembled parts not clean.
Crossed threads.
Threads or serrations damaged.
New gaskets not used after assembly.
Wrong size or wrong material for gasket.
Not enough support for tubing.
Distance between supports too great.
Mismated parts (AC-AN).
Using tubing as handrail or step.

ATTACHING FITTINGS

SOLDERED FITTINGS can be used only on copper. Since the annealing temperature is higher than that of

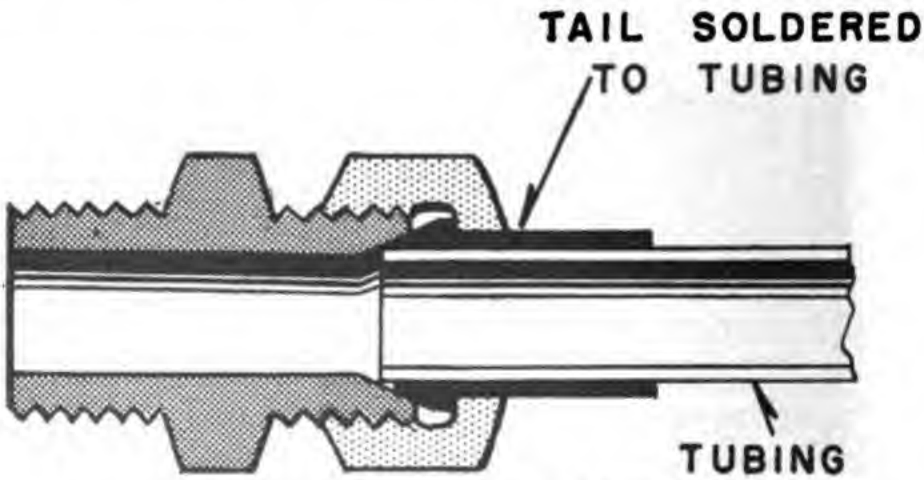


Figure 223.—A soldered fitting.

SOFT SOLDER, you should use SILVER SOLDER on the tubing. The soldered fitting uses a union tail which is slipped on with the nut. The tail is soldered flush with the end of the tubing, after which the fitting is screwed together like any of the other types. Figure 223 illustrates a soldered fitting.

Any fuel line which is directly connected to the engine must be equipped with a flexible joint. This flexible joint is usually a rubber hose fastened with hose clamps to the end of the tubing to lessen the danger of failure. If you have to replace flexible metal tubing, it

is best to substitute pieces of the proper length and of special construction which have fittings attached by the manufacturer. Standard pipe fittings CANNOT BE USED.

Fittings made to be used with hose connections are

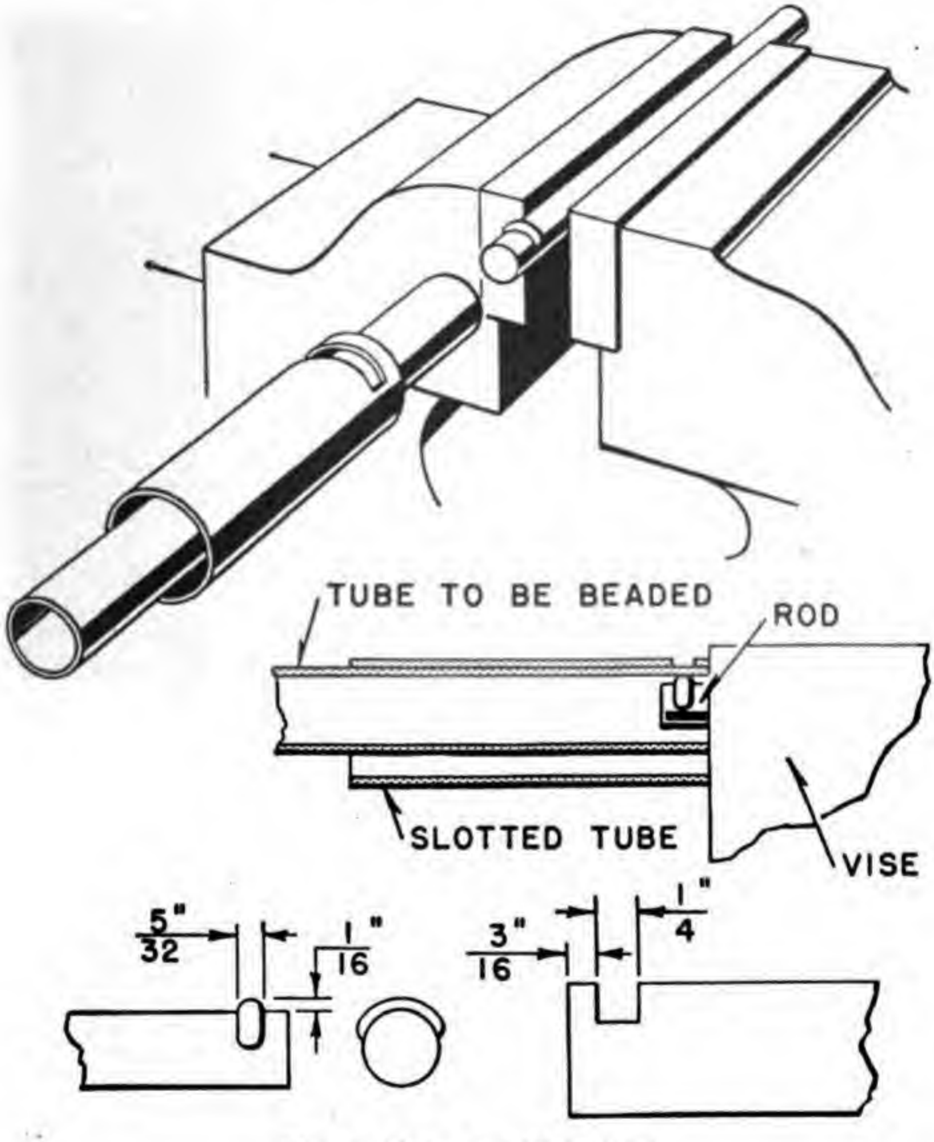


Figure 224.—Beading tool.

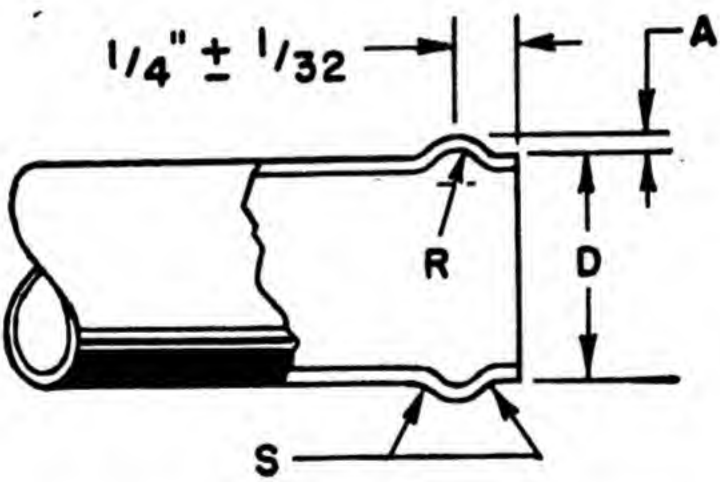
usually beaded at the unthreaded end to make a tight fit. A bead is a raised portion at the end of the tube which helps to hold the hose in place and, by pressing into the rubber, makes the joint watertight.

Making the joint by means of a hose connection is

TABLE XV

Standard Dimensions for Hose Connections

Tube O.D. D	Bead Height A	R Rad. Max.	S Rad. Max.
	+.003		
1/4	.038	1/8	1/16
3/8	.038	1/8	1/16
1/2	.038	1/8	1/16
5/8	.038	1/8	1/16
3/4	.038	1/8	1/16
1	.062	5/32	3/32
1 1/4	.062	5/32	3/32
1 1/2	.072	5/32	3/32
1 3/4	.072	5/32	3/32
2	.082	5/32	3/32
2 1/2	.082	5/32	3/32
3	.082	5/32	3/32



simple to do. Cut the ends of the tubing absolutely square. After the burrs have been removed, bead the ends with a tool like the one shown in figure 224.

The bead size should be standard. Check it against the table XV. The connecting piece of hose should be about 3 inches in length. And the ends of the tubing should be located approximately in the center of the piece of hose and about 1/16 to 1/8 inch apart.

Place the hose clamps directly behind the beads and tighten them securely. A hose liner must be used on the INSIDE of the flexible hose when the connections are made in order to keep fuel from coming in contact with the hose.

A while back you were warned against confusing the markings on tubing which indicate the USES of the lines and those which indicate WHAT MATERIAL they are made of. Table XVI gives the color system used by the Navy to designate the USES of the various lines. For instance, red indicates that the line carries fuel. Each color strip is approximately ½ inch wide. A single color or a combination of colors is used.

TEMPORARY REPAIRING

As you saw before, the temporary method of tube repairing should be used only when time and facilities

TABLE XVI

COLOR CODE FOR TUBING LINES

COLOR	SYSTEM
Red	Fuel
Yellow	Oil (lubricating)
White	Coolant (water)
Brown	Fire extinguisher
Light blue	Flotation equipment
Light green	Oxygen
Black	Airspeed—pitot pressure
Light green—black	Airspeed—static pressure
White—black—white	Coolant (prestone)
White—light blue	Manifold pressure
White—light green	Vacuum
Light blue—light green	Air pressure (compressed)
Light blue—black	Steam
Light blue—yellow	Purging
Light blue—brown	Exhaust analyzer
White—red	Fluid (ice preventive)
Red—black	Vent (closed compartments)
Light blue—yellow—light blue	Hydraulic pressure oil

will not permit permanent replacement. Figure 225 will give you a clear idea of the steps to be taken.

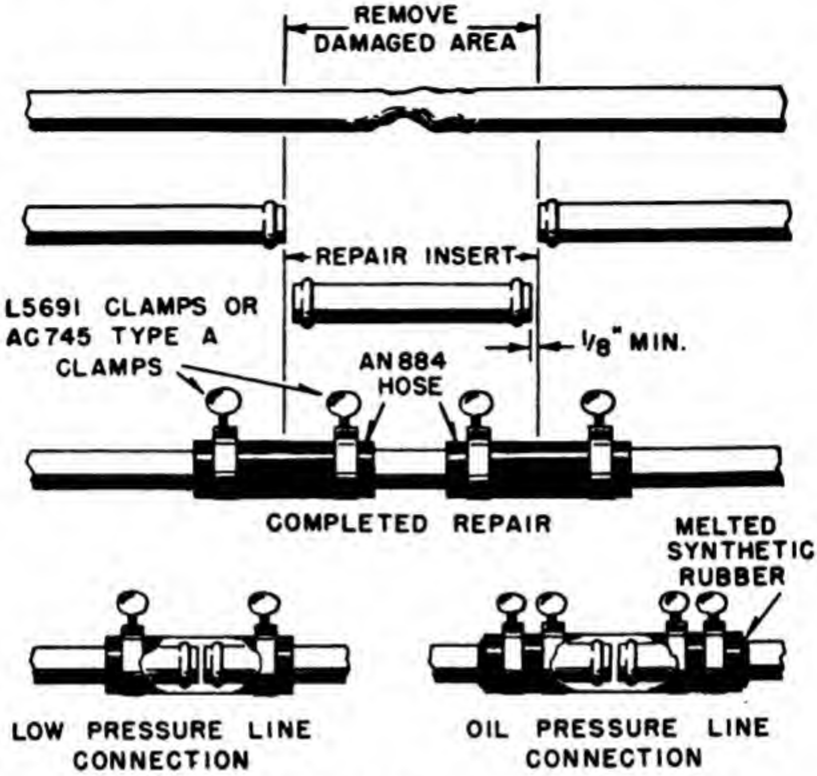


Figure 225.—Steps in insert type repair.

First cut out the damaged section of tubing. After you have done that, cut a length of new tubing to replace the damaged section.

Bead each end of the insert and each end of the tube being repaired.

Cut proper lengths of suitable hose, and install the repair, using the hose and hose clamps to hold the new section in place.

CHAPTER 8

PLASTICS

ONCE A MAGIC WORD

Not so long ago PLASTICS was a magic word in industrial chemistry. The countless things for which this material is used are still surprising, but many of its most vital uses, especially in airplanes, have begun to be commonplace.

The use of plastics in aircraft so closely parallels the use of sheet metal, that the Aviation Metalsmith must understand both materials if he is to do his job well.

Chief characteristic of the substance, and the one for which it was named, is the ease and readiness with which it may be molded. Plastics may be cast and machined, laminated and rolled, and even used in paints and as an adhesive for plywood bonding.

MOLDED PLASTICS are of two general classes—THERMOSETTING and THERMOPLASTIC compounds. To understand the distinction between the two, think of

thermosetting compounds in terms of concrete. In other words, once these plastics "set," their form is permanent. On the other hand, THERMOPLASTIC compounds might be compared with sealing wax. At room temperature sealing wax is a dense, hard substance. But heat it, and what happens? It becomes soft and pliable, and can be formed into any shape you may desire. Cool it again and it maintains that shape until it is again re-softened by heating. Like sealing wax, THERMOPLASTIC materials can be softened by heat and hardened by cooling again and again without a resulting chemical change in the composition of the materials during the heating and cooling process. The tendency of plastic sheet to resume its original flat shape on reheating is known as "elastic" or "plastic memory."

As an Aviation Metalsmith, you will have very little to do with the thermosetting plastics—except possibly to replace worn out and damaged pulleys, fairleads, and electrical insulation material. For this reason no further information on thermosetting plastics is given here.

TRANSPARENT PLASTICS

TRANSPARENT PLASTICS are those which allow sufficient light to pass through for good vision. Plastics like those used for cockpit enclosures must be 87 to 90 percent transparent EVEN AFTER severe Navy tests that duplicate the actual effects of sun and weather.

Two types of plastics are used in airplanes.

Acrylates (methyl methacrylate).

Acetates (cellulose acetate).

The acetates, because they are comparatively cheap, are used in some basic training planes. The acrylates are used in combat planes. The most common types of acrylates are Lucite and Plexiglas.

The acetates are limited in their use because they discolor, or damage easily, and are not easy to repair. Both the acrylates and the acetates are thermoplastic transparent plastics.

These transparent plastics are manufactured as castings, rods, sheets, tubes, and molding powders. Cast sheet, in its most useful form for aircraft work, comes in thickness from .060 to 0.25 inch for acrylate plastic, while acetate plastic comes in a thickness from .0156 to .500 inch. They range in size from 24 x 36 inches to 20 x 50 inches. These sizes may vary slightly and it may be necessary for you to refer to Navy Technical Orders governing sizes. Sizes other than standard may be obtained by special order.

HOW TO TELL ACRYLATES FROM ACETATES

In repairing transparent plastics, you will find you have to know the kind of plastic involved. The reason is that the method for repairing acrylate plastics may be injurious to acetates, and vice versa.

Furthermore, acrylate patches will not adhere on acetate enclosures, and vice versa. There are three tests that can be used to tell which is which; they're listed in the order of their reliability—

BURNING TEST—Both types will burn much like wood. The acrylates burn with a steady clear flame and give off a sweet wine-like odor. The acetates burn with sputtering flame with a dark smoke and a sticky residue which drops from the burning portion. The odor is repulsive with a vinegar tang to it. (Of course, this test must be done with scrap pieces from a broken enclosure.)

HARDNESS TEST—Scratch the surface of the plastic with a sharp instrument. Acrylates are much harder than acetates. Scratching a piece of acrylate is similar in order to cutting glass with a glass cutter. The scratching of acetates is similar to running your fingernail through a bar of soap. Edges of acrylates CHIP, whereas acetates CUT.

ACETONE TEST—Wet your finger with acetone and rub it on some spot that will not interfere with vision. Then blow on the spot. If the plastic is an acrylate, it

will turn a smoky white. An acetate will be softened somewhat, but will not change color.

STORING

You are stationed at a base and in comes a supply of plastic sheet from the states. How are you going to store it in order to preserve it for use at the time when it is needed?

A plastic sheet is best stored on edge or flat on its side. Stored at an angle for any considerable length of time, the sheets may sag or bow. If this should happen, however, don't worry too much—it's only a temporary deformity and can be corrected by simply reversing the sheet and allowing it to stand tilted at the opposite angle until it assumes its original flat shape. If the plastic is stored flat, the larger sheets should be placed on the bottom.

Keep the storage room cool (not over 120° F.), moderately moist, and well ventilated. If your storage room is allowed to become hot and dry, the rubber adhesive used to cement the masking paper to the plastic hardens and may become extremely difficult to remove. On the other hand, too much moisture causes the paper to deteriorate, thus losing its effectiveness in protecting the material.

The storage room should be located so that the plastic will not come in contact with thinners, solvents, or their vapors, which may attack and soften the surface of the plastic.

You can't keep the sun from shining, but you CAN keep it from shining on plastic sheets. Direct rays of sunlight falling on plastic material eventually [illegible] breakdown of the masking cement, especially at the edges of the sheets. To remove broken down cement apply a mixture of oil and kerosene, then wash.

HANDLE WITH CARE ALL FORMED SECTIONS if you want them to retain their shape. STEAM AND HOT WATER PIPES ARE ENEMIES of formed plastic, so make

a special effort to avoid all contact with these. A few simple frames large enough to cover the pieces, and stacked together in your spare moments are excellent for relieving formed pieces of unusual pressure.

Since most transparent plastics used in Naval aircraft are flame resistant, their storage does not constitute a fire hazard any more than similar stocks of wood.

UNMASKING

To protect their surfaces, most plastic sheets are supplied with tough paper applied with a pressure-sensitive rubber adhesive. This paper helps prevent accidental scratches from appearing on the surface of the sheet during storage and fabrication. (The adhesive for masking paper used on ACETATE plastics cannot, according to Navy specifications, contain a rubber resin base "because of the deleterious effects on the plastic.")

DO NOT REMOVE THE MASKING PAPER until the last moment. Keep the sheet covered, because you MUST KEEP IT CLEAN.

When you are ready to remove the masking paper, lift it at one corner, then roll it off like you would roll a rug. If specks of adhesive stick to the plastic sheet, they can be removed by simply dabbing the specks with pieces of the masking paper.

If the masking paper has become hardened and stuck, it may be softened by wiping it with a cloth soaked in hexane or kerosene which will soak through the paper and soften the adhesive.

Never use a scraping tool to remove masking paper, because the plastic is certain to be damaged, often beyond any chance of use.

Unmasking builds up an electrostatic charge on plastic sheets, attracting dust to the surface. If you blot the sheet with a damp chamois, you can remove the dust. If the weather is very dry, it is a good idea to wet the floors of the storage room occasionally to cut down the amount of dust in the atmosphere.

CLEANING PLASTIC

Whenever transparent plastics are used in aircraft that are in service, you may be sure they will need frequent cleaning to get rid of foreign matter clinging to the surface—dust, dirt, grease and other materials. The idea is to maintain the HIGHEST POSSIBLE DEGREE OF TRANSPARENCY. One important precaution you must take is to AVOID RUBBING DIRT OR GRIT INTO THE PLASTIC, because it scratches the surface.

TO CLEAN EXTERIOR SURFACES, flush the surface with plenty of water and use your bare hand to locate and dislodge any dirty or foreign particles that might cling to the plastic.

Another way to clean the outside surface is simply to wash it with soap and water. Use a soft cloth, sponge, or chamois to carry soapy water to the plastic. Go over the surface lightly with your bare hands to detect and remove any dirt before it scratches the plastic. Remove oil and grease by rubbing the surface with a cloth moistened with kerosene, hexane or white (not aviation or ethyl) gasoline.

Do NOT use the following materials on acrylate plastic—acetone, benzine, carbon tetrachloride, fire extinguisher fluids, lacquer thinners or window cleaning spray. These fluids may cause crazing of the surface if you use them. (Crazing means the appearance of a number of small surface cracks which interfere with vision.)

Acetone in lacquer thinners or window cleaning sprays have a definite softening and blurring effect on acetate plastics. Therefore, know your plastic before cleaning it. And know your cleaners, too.

Don't rub acrylate plastic WITH A DRY CLOTH. A dry cloth is not only likely to cause scratches but it may also build up an electrostatic charge which attracts dust to the surface. If the surface does become charged, you can remove the charge by patting or blotting the

surface gently with a damp, clean chamois. The chamois will also take off the dust.

If, after you have removed the dirt and grease, you find no great amount of scratches visible on the surface, wax the acrylate plastic with a good grade of commercial wax. Some acceptable waxes are PERMASEAL, SIMONIZ wax, 3 M Auto wax, and DUCO No. 7. These waxes will cover minor scratches and will prevent further scratching. Apply a thin even coat of wax and polish with a soft, dry cloth.

TO CLEAN INTERIOR SURFACES, you can't use the methods just outlined because water cannot be applied freely. Instead you can dust the plastic surface lightly with a soft, dry cloth. But DO NOT WIPE the surface.

Another way to clean an interior surface is to wipe it carefully with a soft, clean, DAMP cloth or sponge. Keep the cloth or sponge free from dirt or grit by rinsing it frequently in clean water. Last of all apply wax as previously described.

POLISHING PLASTICS

If, after you have cleaned the plastic you find that the surface is marred by a number of light scratches which are not deep enough to warrant sanding, but which ARE pronounced enough to reduce visibility, then you must polish the plastic by hand, machine, or buffing. If you do it right, you can remove the light scratches and restore the plastic's transparency.

To polish the plastic BY HAND use a small pad of flannel or other soft cloth and apply a suitable cleaner. Avoid rubbing the same area too long or too hard in one place, because excessive friction may build up heat enough to soften the plastic.

Some of the suitable cleaners are—Franklin's triple life cleaner and glaze, Noxon cleaner-polish, Autogroom, Ken-glo, Lincoln M-3828 cleaner, Wilco scratch reremover, Simoniz liquid cleaner, Duco No. 7 liquid cleaner, or McAleer's airplane polish.

While you can remove most scratches in a short time, some scratches like those caused by sanding may require several applications of the cleaner. After you have polished the surface as to near the original transparency as possible, put on a thin coat of wax and polish it to help protect the surface against further scratching.

Often after cleaning and polishing, some scratches will still remain. They will have to be taken off by a machine buffing procedure.

You should use soft, open cotton or flannel buffing wheels on acrylate plastic. If no commercial wheels are available, make one by assembling a number of disks of cotton muslin or flannel on a spindle between large washers or face plates.

A harder wheel may be made by mounting disks of a thick felt (½ to ⅝ inch) in the same manner. For shop use they may be mounted on grinder shafts or on buffing lathes. Special portable buffing equipment is also useful.

For buffing a plastic section without removing it from the aircraft, use small wheels from four to six inches in diameter like those in figure 226. These wheels are mounted in the chuck of a portable electric drill, of from ¼ to ⅓ hp. Or, they can be mounted in an airdriven drill motor.

Standard buffing or coloring compounds of very fine aluminum or similar abrasive are used with a wax, tallow, or grease binder. The FINEST GRADES are as coarse as will be necessary for acrylate plastics. Clean buffing tallow or wax may also be used.

Since the transparency of plastics must quite often be IMPROVED by buffing, you had better be sure to follow the procedure outlined.

Be sure the plastic surface is clean before you start to buff.

Check up on its cleanliness between each step of the procedure.

Hold the tallow stick against the spinning wheel for a few seconds.

Next, bring the bar of buffing compound in contact with the wheel for a few seconds.

Apply the edge of the spinning wheel, using a light pressure only, to the surface of the plastic and keep it moving. Excessive pressure may heat and soften the plastic. Buff along and across any scratches.

When the scratches are removed, wipe the buffing compound carefully with a soft cloth.

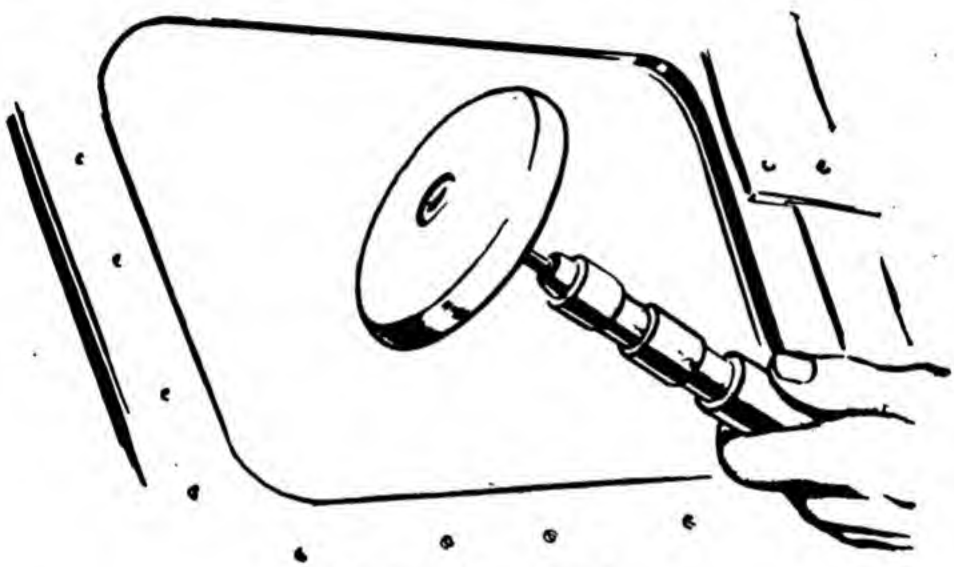


Figure 226.—Buffing.

Insert a second wheel, usually the soft, open type, in the power tool. Apply only tallow to this wheel. It is essential that you use a second wheel because some of the buffing compound will be retained by the first wheel.

Go over the surface of the plastic with the tallow wheel, observing the same precaution given above. Wipe the tallow from the plastic.

Apply a thin coat of wax and polish by hand.

The plastic is next brought to a high polish on a buffing wheel on which NO abrasive or tallow is used. That is necessary to secure high gloss and luster—otherwise the plastic assumes a foggy appearance.

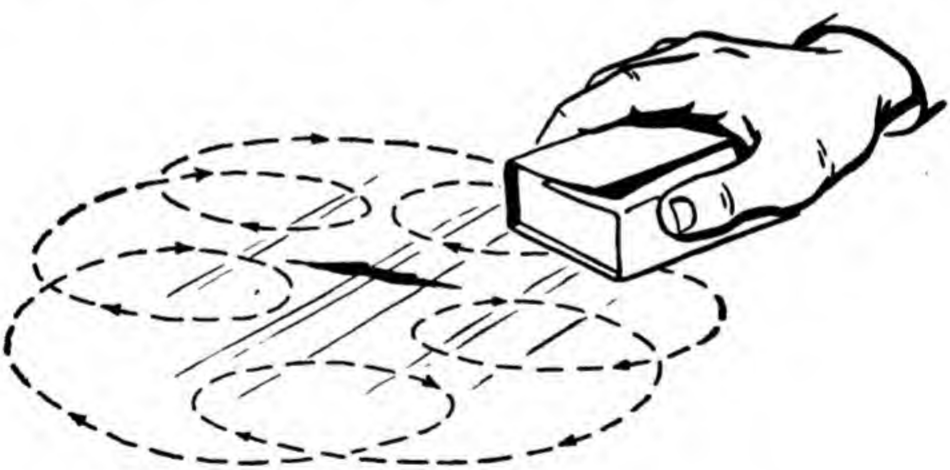
Under NO circumstances should buffers that are used to buff metal (regardless of what metal) be used on plastic. Fine particles of metal remain in the wheel and scratch the plastic.

Acetates and acrylates respond to buffing differently. Acetates heat more rapidly and distort themselves more easily than do acrylates. Greater care must be taken in buffing acetates. Scratches do not buff out as readily in acetates as acrylates.

The speed for buffing acetates is lower than for acrylates. For example, an 8 to 10 inch buffing wheel for acrylates travels at about 2,000 rpm; whereas one for acetates travels about 1450 rpm.

SANDING

Transparent plastics SHOULD NEVER BE SANDED unless it is absolutely necessary—and THEN only when



SAND WITH CIRCULAR MOTION WITH LIGHT PRESSURE

Figure 227.—Sanding.

surface scratches which impair vision are too deep to be removed by buffing.

The sandpaper you choose should be the finest that will remove the imperfections. Wet or dry types in grades of 320A to 600 are recommended.

To sand plastic, start with grade 320A soaked in water a few minutes. Use plenty of water while sanding to reduce the heat of friction. Wrap the paper around a block as in figure 227, and sand an area slightly larger than the damaged space. Use a circular motion with a light pressure to reduce the chances of objectionable visual distortion to a minimum.

Visual distortion, whether it's caused by improper buffing or sanding, is referred to as "hazing."

Work with progressively finer grades of paper until you get to grade 600. Be sure to wipe off the sanded area with a clean, dry cloth after each sanding operation to prevent the coarser grit from clinging to the plastic.

The fine scratches produced by sanding can be removed by buffing if the equipment is available. Otherwise, you will have to hand polish the surface and as a final step, give it a coat of wax.

CUTTING

As a guide to sawing plastics, it is common practice to scribe the surface lightly with a sharp scriber. Thin sheets, up to .080 inch, can be broken along a straight scribe line, much like a piece of glass, provided the line is deep enough.

Unlike glass, transparent plastic MAY BE CUT with any of the SAWS USED FOR WOODS AND METALS. However, if the same hand and power saws are used in your workshop for plastics as for the other materials, there is one "DO" which you must observe. Do take extra precaution to see that all metal filings and similar material are carefully removed from the tables before the plastic sheets are laid out, since these filings may scratch the sheets even through their masking paper.

If there is a great deal of plastic to be cut, it is best to reserve special saws. For cutting plastic up to .100″ thick, you may use blades with fine teeth and little set. For thicker plastic you should use a combination saw

alternating 4 cutting teeth with one cleaning tooth. It should have 8 to 22 teeth per inch.

To obtain an accurate cut and avoid overheating, feed the sheet to the band saw slowly. No coolant will be required if you take reasonable care to avoid overheating. However, if you find a coolant is needed, use soap and water, light machine oil, waxed paper, or air blast. Band saws used for cutting plastic sheet should run at 8,000 to 12,000 surface feet per minute. Circular saws having a diameter of 12 inches should run at the rate of approximately 3,400 rpm. Since most transparent plastics contain no filler or plasticizers, the saws used in the cutting process do not gum up or dull excessively.

Acrylate and acetate plastics may be readily filed, scraped, or sanded to give a desired finish. Vixen, rough cut, or medium cut files will give the best results.

DRILLING

In your career with plastics you're going to find it necessary to DRILL HOLES—for example at the end of crack to relieve strains, or to provide a means of attaching panels by riveting, bolting and screwing. Holes are also necessary when making a laced repair. Vertical spindle drill presses are most practical for drilling acrylate plastics. Portable hand drills may be used but they aren't as accurate.

The standard drills used for metal may also be used for drilling plastics. Drills with wide flutes are preferred, because they permit the chips to free themselves more easily. To prevent cracking of the plastic in drilling, you must grind down the drill so that it has a lip angle of 70° or a point angle of 140°. The lip clearance angle should be 4 to 8 degrees as in figure 228.

This flatter point allows the body of the drill to enter the work BEFORE THE POINT BREAKS THROUGH. Thus, a wedging action is prevented. Blunter drills do not "grab" into the plastic as readily; so they're less likely to

cause injury to the operator and damage to the plastic.

The feed for drilling plastic is much slower than that for drilling metal. You should DECREASE the rate of feed as the depth increases. Too fast a drill feed causes plastics to crack and chip. When you use the correct feed, you will get smooth, spiral chips.

When you are drilling plastics it is necessary to provide some means of cooling the material to prevent BINDING and GRABBING of the drill. Three of the most

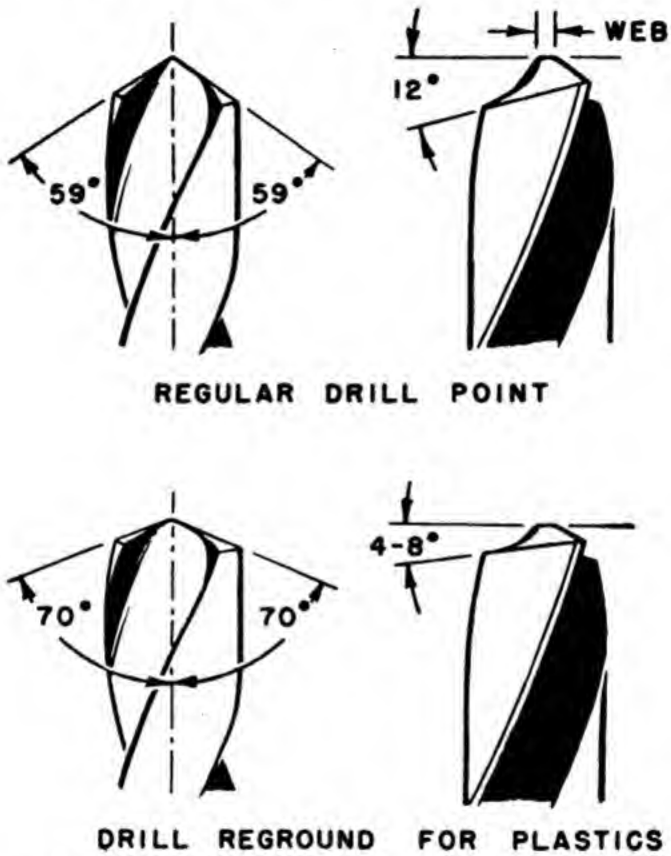


Figure 228.—Drills for use on plastics.

commonly used coolants are mild soap and water solution, light machine oil, and the cool air jet. However, on thin stock coolants are not necessary if the plastic is drilled slowly and the bit moved out of the hole occasionally.

Drilling plastics is not a dangerous job, but you WILL have to follow a few simple rules in order to do safe and accurate work.

Use a sharp drill ground to the proper angle.

Use the proper speed and feed.

Use coolants.

Lift the drill occasionally to free any chips and prevent binding.

Use goggles or face shield to protect your eyes.

TAPPING AND THREADING

Tapping and threading of transparent plastics is done in the same manner as it is on metals. It may be done either by hand or machine. Sharp "V" threads should be avoided. Lubricants to use for tapping and threading are either a mild soap and water solution or oil. Hand tapping and threading of holes and rods $\frac{3}{16}$ inch in diameter or less requires no lubrication at all. Plastics should be tapped MORE SLOWLY than metal.

Don't do any tapping and threading in places where the threads would be likely to undergo vibration and stress. If you are threading and tapping an acrylate plastic to fit a metal bolt, you must make allowance for the difference in thermo-expansion of the two materials.

Use threaded metal inserts where temperature variations are extreme or where threads must withstand high stresses. These metal inserts are fitted into the plastic instead of threading the plastic itself.

EMERGENCY REPAIRS

Repairs to plastics may be made necessary by SCRATCHES, CRACKS OR BULLET HOLES. Ordinarily, badly damaged panels are replaced. If the damage is not too severe either emergency or permanent patches may be applied. A part that has been repaired with a permanent patch is approximately 85 percent as strong as the original.

The first step is to determine whether the panel is made of glass or plastic. An easy way to find out is

to press the point of a scriber—or any pointed tool—against the material. If the point leaves an impression, the panel is made of plastic.

You will do an emergency repair job when something must be fixed in a hurry with a minimum of equipment. An emergency patch should be replaced, however, as soon as possible with a permanent patch. Or, a new panel should be inserted.

Emergency repairs obstruct vision, are not weatherproof and are not durable enough to withstand the stresses imposed upon them. They can be made in any of the following ways, whether the repair is to a crack, or to a bullet hole.

Suppose you want to make a LACED PATCH. The first step is to drill a 1/8 to 3/16″ relief hole at the end of the crack as in the first drawing of figure 229. This relief hole distributes the stress over a greater area and prevents the crack from spreading. The hole must be DIRECTLY AT THE END of the crack if it is to serve its purpose.

The next step is to drill 1/8″ holes down both sides of the crack, spaced 1/2″ from the crack on both sides and 3/4″ apart. Place the beginning set of holes slightly beyond the relief hole, to offer additional support for the relief hole. Use copper wire, strong twine or a shoe lace to secure the crack in much the same manner as you would lace up your shoe. The lacing should be under even tension.

Another way to fix the crack is to use a FABRIC PATCH. Grade "A" airplane fabric canton flannel, part of a shirt, or similar material can be cemented over the damaged part after the relief holes have been drilled. This repair can be used either on cracks or on bullet holes which have radiating cracks. Each of these radiating cracks should have a 1/8 to 3/16 inch relief hole drilled at its ends, as in figure 229.

Soak the fabric in plastic solvent or cement and then apply it to both sides of the panel. In an emergency, you can use acetate dope, but it doesn't offer much

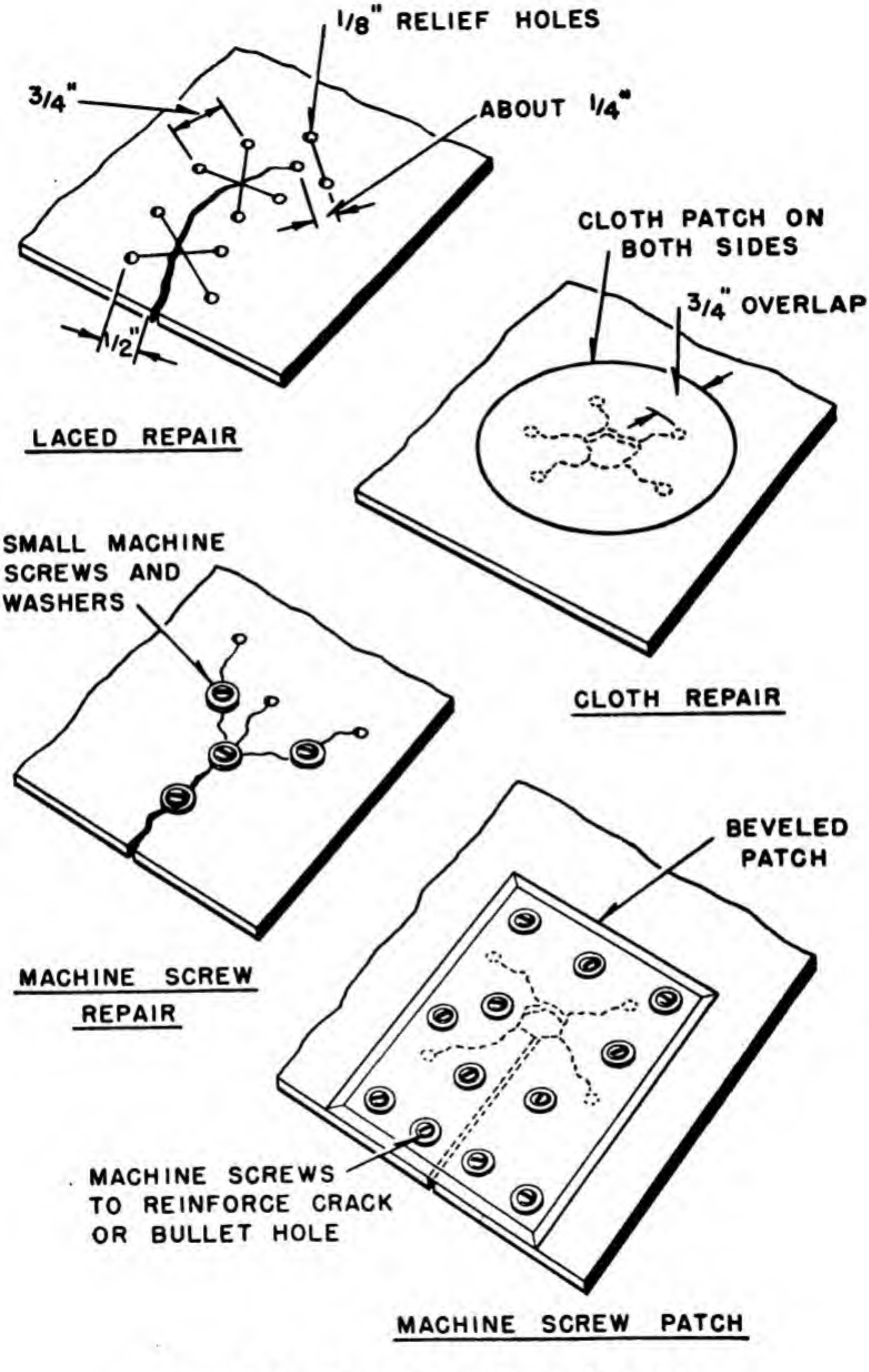


Figure 229.—Emergency methods of repairing.

reinforcement because it is not a very effective cement.

A cloth patch used on acetate plastic can be applied very readily with acetate dope, if no cement made out of acetone is available.

A simple BOLT REPAIR may be used for quick repairs to a badly shattered area. In that case you drill the necessary relief holes. The repair from there on may be done two different ways. The simpler method is to repair a cracked piece of plastic in much the same way as you'd fix a cracked automobile windshield or plate glass window by the use of bolts. A second way, if a section is severely shattered and time does not permit even a temporary lap patch, is to bolt a piece of plastic over the top of the damaged area.

SEMI-PERMANENT REPAIRS

Another way to repair cracks and bullet holes is to use a LAP PATCH such as you see in figure 230. This is a semi-permanent repair, since it takes several days to do a finished job. It partially obstructs vision so it should be REPLACED when possible. In making this repair you use a piece of the same plastic (thickness and kind) as the original, and cement it over the damaged area. The shape of patch depends on the amount of damage. The patch itself should be beveled and highly polished. It should overlap the damaged area about ¼ inch. Form it to the contour of the piece of plastic that you are repairing. (Forming will be explained under the section on that subject.) Be sure the relief holes are drilled at the ends of all cracks.

The patch may be cemented either with wood glue or by the soaking method—both of which will be explained in the section on cementing. Place tape on those parts of patch and panel which are not to be cemented. The patch may be held in place either by a moderate amount of hand pressure or by weights. This patch should be left to dry for from 24 to 36

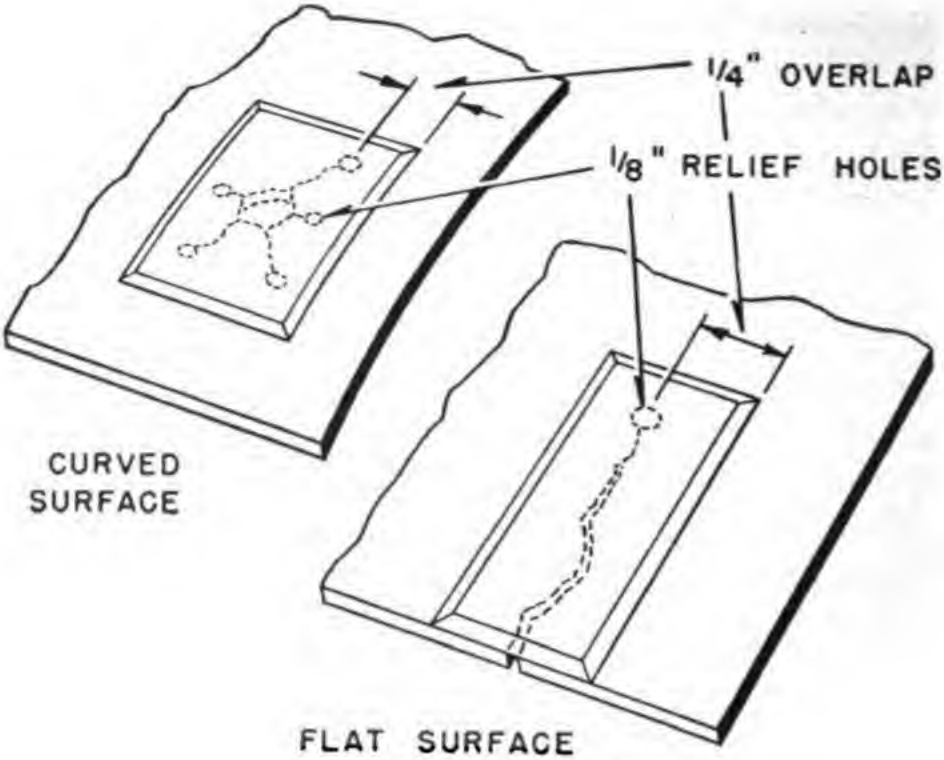


Figure 230.—Lap patch.

hours before it is buffed and polished, to improve its transparency.

PERMANENT REPAIRS

You can permanently repair a crack or bullet hole by cutting out the damaged area and replacing it with A PLUG OF THICKER MATERIAL.

Trim the hole to a perfect circle or oval and bevel its edges about 30°. File the plug to fit the hole and bevel the edges of the plug TO A SHARPER ANGLE than those of the hole. You can see this sharper angle in figure 230.

After you have shaped the plug so that it will fit the hole closely, heat it until it is pliable and force it into the hole UNDER A LIGHT PRESSURE to insure a perfect fit. After the plug has cooled, remove it, tap it, and cement it into place, as in figure 231. Let it stand for 24 hours, then sand the plug flush with the panel. Finish the job by buffing and polishing.

The soak method of cementing is often preferable. The plug should not be sanded and worked down for three to ten days, depending on the thickness of the cushion of cement. Finish the job by buffing and polishing.

CEMENTING

If you practice and are careful, it is possible for you to obtain a cemented plastic joint which approximates VERY CLOSELY the original plastic in strength and transparency.

There are a number of different cements which will hold two pieces of acrylic plastic together. Here they are.

MONOMER is a liquid acrylate, kept in liquid state by the addition of a reducing agent known as hydroquinone. This is a commercial cement and is often known as Cement X or, Cement 1A. It is used especially in the SOAK METHOD of cementing.

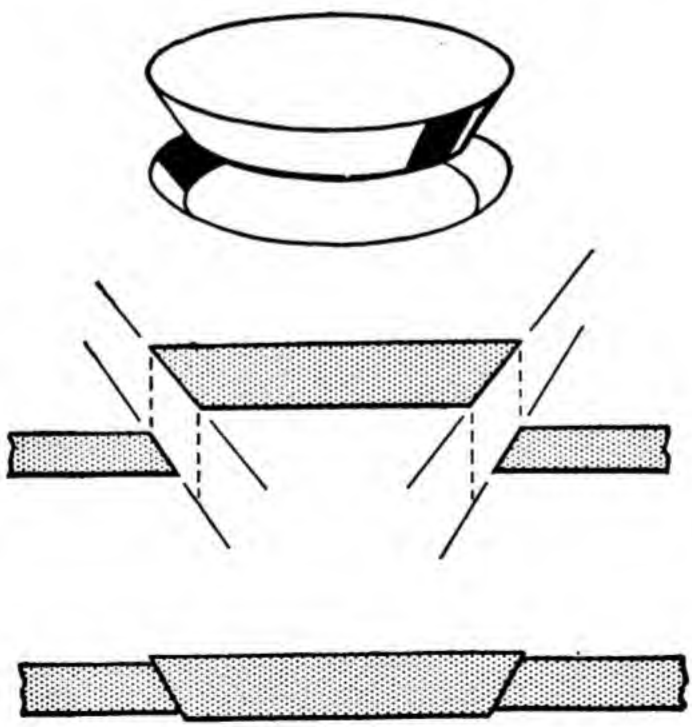


Figure 231.—A permanent patch.

Monomer solvent. In this type of cement, as much as 50 percent methylene dichloride is added to the monomer to improve its penetrating power. This type of cement is also used for the soak method.

Solvent cement. The value of this cement lies in its ability to SOFTEN the surface of the acrylic plastic. As the two pieces are brought together, the solvent evaporates and the plastic hardens. The four solvents commonly used are ethylene dichloride, methylene dichloride, glacial acetic acid, and acetone. Ethylene and methylene dichloride have proved to be the best. Acetone should be used as AN EMERGENCY SOLVENT ONLY, as it tends to leave the surface of the plastic cloudy and hazy.

Partially polymerized monomer. To produce this kind of cement, ordinary monomer cement is heated to its boiling point which is near that of water. This cement is HIGHLY INFLAMMABLE. To prevent fire, boil the monomer over an electric hot plate rather than an open flame. After the cement has cooled, it is a little more viscous than glycerine. Use this cement in the same manner as you would glue. You must keep it in a refrigerator to retard hardening.

Solvent polymer cement. This is one of the most commonly used cements and is easy to prepare. Ethylene dichloride, methylene dichloride or glacial acetic acid, may be used as a solvent. In each case ordinary acrylate chips or shavings are added to the solvent until a viscous cement is produced. As the solvent evaporates and the cement hardens, more solvent must be added to keep the cement at the proper viscosity. This cement is also used in the same manner as wood glue.

Most of the solvents and cements are highly inflammable. Keep them in a cool, well-ventilated place, free from dirt or any other foreign particles. Don't mix or store them near an open flame.

For best results, be sure that the pieces of plastic

that are to be cemented fit accurately. All jointed areas should be sanded smooth and cleaned of any foreign substances, preferably with wood alcohol or with soap and water.

Parts that are not to be in direct contact with the cement SHOULD BE TAPED to prevent the cement from marring the plastic. Masking tape should be used on joints to protect the surrounding area. The reason for this protection is that plastics REACT to cement and would be distorted or lose their transparency if they weren't protected. Figure 232 shows how the tape is applied.

Some tapes are resistant to the action of the cements

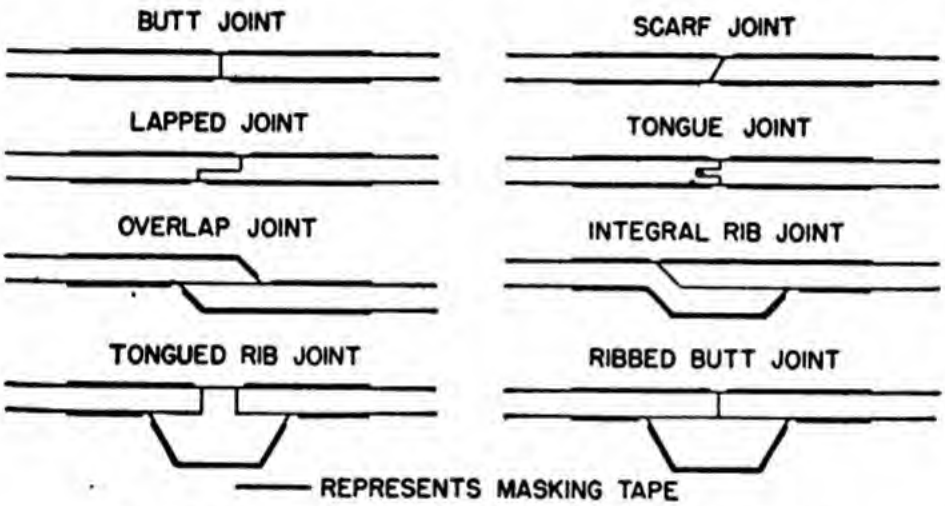


Figure 232.—Taping for different types of joints.

used for plastic and others are not. You can test the effectiveness of your tape this way. Tape up a piece of plastic and soak it in the cement to be used for a short time. If after the tape has been removed, there are indications that the cement has worked its way under the tape, then it is unsatisfactory. If the plastic remains unaffected, the tape is OK.

There are TWO METHODS OF CEMENTING. One is the SOAK method and the other, the WOOD GLUE method.

If you use the soak method, the first thing to do is to tape the joint to within $\frac{1}{16}$ inch of the area to be cemented.

Next place the joint in the cement. Either solvents or monomer may be used. Let the joints soak for a period of time, the length of which depends upon the type of cement.

If ethylene dichloride is used, soak the joint for 15 to 20 minutes. If monomer is used, soak it for 30 to 45 minutes. The time the piece is left in the cement will vary according to the depth of the cushion desired. After soaking, clamp the joint in position and let it stay until it is dry.

If you use the WOOD GLUE METHOD, tape the joint to within 1/32 inch of the area to be cemented. Apply the prepared glue to the joint just as you would brush glue onto a wood joint.

Apply just enough pressure in clamping to force out all the air bubbles from the surface of the edge. In many cases, the success of a cementing job will depend upon the method used for clamping the joint together while it dries.

You should space clamps or jigs evenly over the surface to keep the joint under as much pressure as is practical. Be careful to see that the two pieces of plastic are not forced out of shape. If that happens, one or the other piece will be crazed.

There are not any set rules for clamping plastics into position. Figure 233 will give you a general idea of how the clamping may be accomplished. Here is a list of items which may be used.

Clamps—battery clamps,
C-clamps, hand screw clamps.
Jigs.
Springs.
Weights.
Rubber bands.
Metal bands.

DRYING TIME

A joint will carry some stress in about 24 hours. However, even at 120° F., the full strength will not

be realized for 10 to 14 days. At room temperature, 30 to 60 days may be required for completely hardening a "soak."

The joint should be thoroughly hard before working. The softened material will shrink until it is fully set, and if the joint is trimmed and sanded too soon a visible scar will be left along the joint.

The preceding information on cementing deals with acrylic plastics. Acetone is the solvent used in making

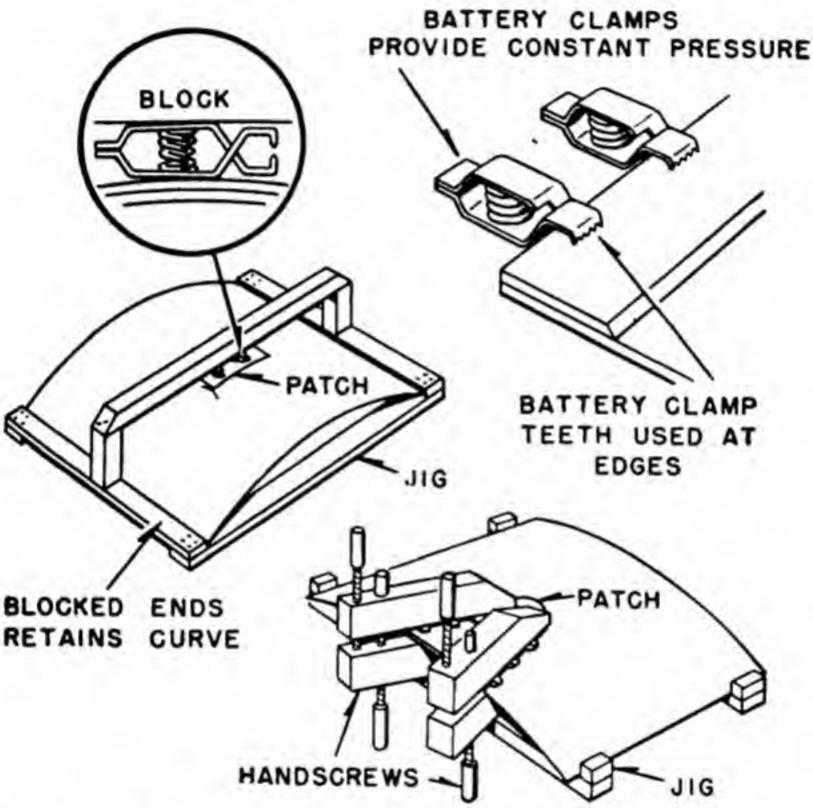


Figure 233.—Cementing with jigs and battery clamps.

a solvent polymer cement. You add acetate plastic chips to the solvent until you have a viscous cement. This cement is used with the wood glue method. Acetone may be used as a solvent in a soaking method, but the plastic should soak a much shorter time than with acrylates (about 4 to 5 minutes). Acetate dope may also be used to cement acetate plastics.

The drying time on acetates is much shorter than on acrylates.

FORMING ACRYLATE PLASTICS

Forming plastics is a process which involves heating to a given temperature for a given length of time and then bending over a form or pattern to obtain the desired shape.

Only the thermoplastics (which include acetates and acrylates) can be formed, of course, since they are the only plastics which can be made pliable by heating.

There are two common types of forming—MONOCURVE, or simple forming, and MULTICURVE, or stretch forming. In monocurve forming, the plastic is bent in ONE DIRECTION ONLY. In multicurve forming, the plastic sheet is stretched so that it is curved in MORE THAN one direction. An example of multicurve forming would be the forming of a ball shaped part over a round form. You have to know how to form plastics in order to repair windows, put in curved panels, make patches and miscellaneous parts.

The forms for shaping plastic may be made of wood, metal, plaster of paris, cement, plastics, or perhaps a combination of these. Where a form is to be used constantly, the material should be of a type that does not shrink or expand.

Finish the form as soon as possible and cover it with felt or canton flannel. The form should be slightly larger than the finished piece to compensate for the tendency of the plastic to curl away from the edge. There should be a trim line at a convenient working level. In addition, clamping jigs should be provided which will hold the plastic down while it is cooling.

Plastics may be HEATED FOR FORMING by any of the following means—electricity, gas, steam, or the direct flame of an alcohol lamp or blow torch IF CARE IS USED. An indirect hot air oven like that in figure 234 is most satisfactory. You can use the oven of an ordinary gas range if it has a temperature control. The sheets of plastic may be hung vertically on clamps or placed in a horizontal position on cloth or felt.

The forming temperature for each plastic is different. For acrylates the temperature range is from 220 to 300° F. Monocurve forming requires temperatures from 248 to 284° F., while multicurve forming requires a temperature nearer 300° F.

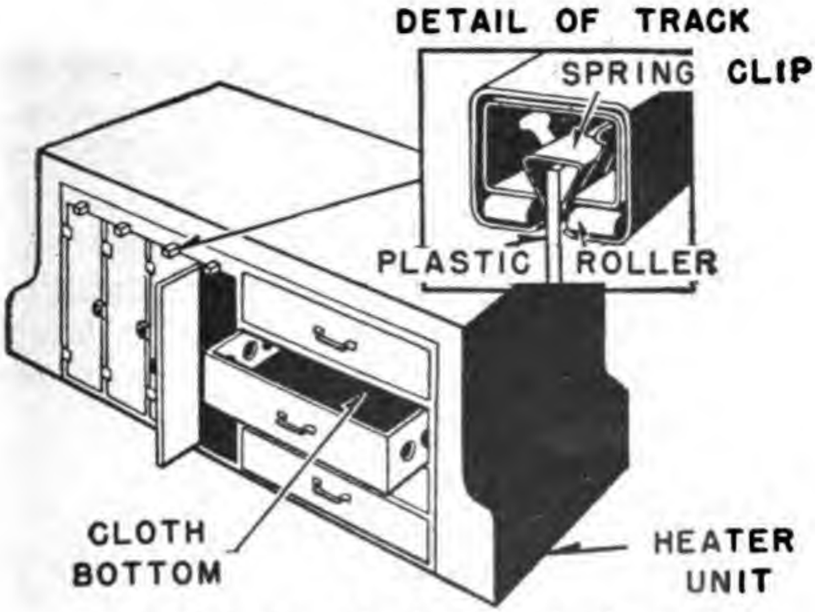


Figure 234.—Oven for heating plastic sheets.

The length of time the plastic remains in the furnace depends upon the size and thickness of the sheet. Usually, it should be heated from five to twenty minutes. Test the plastic by grasping one corner. If it is very pliable, it is ready to form. You can keep strains in the plastic to a minimum by making sure that the material is properly heated BEFORE attempting to form it.

If it is too soft, flaws may develop. Two of the common flaws are MARK-OFF and CRAZING. Mark-off is a term applied to imperfections and indentions which are pressed into the soft plastic from a badly made form, or which are caused by handling the hot sheet incorrectly. Crazing can be produced by attempting to form a sheet that is not hot enough, by abnormal stresses applied to the sheet, or by using the wrong types of cleaners.

ALWAYS WEAR soft cotton gloves when you handle heated plastics, to avoid developing flaws in them. You should always handle the sheets at the edges or in spots that are to be cut away. Remove the protective masking paper BEFORE HEATING, or it will bake out the plastic. If the plastic is washed before heating, you must remember to dry it, since the compounds in tap water will also bake into the plastic if they are not removed.

Don't take the plastic away from the form until it has cooled THOROUGHLY.

In forming acetates, greater care should be taken than with acrylates. Why? Acetates blister more readily than acrylates, and they require a lower heat range than acrylates. Use only the LOWER acrylate heat range on acetates.

INSTALLING PLASTICS

"Installation" means the replacing or attaching of plastic panels and parts by the use of various types of mountings and attaching devices. There are several types of these devices. The following list includes some of the more common ones.

Extruded U or H channels.
Flush channels.
Ribbed channels.
Wedge section installation.
Nut, bolt and rivet mountings.
Patented channel installations.

Some of these installations are shown in figures 235 and 236. Whenever possible, bolting and riveting THROUGH HOLES DRILLED IN PLASTICS should be avoided. Channel and clamp mountings are better because they are easier and quicker to install.

Sometimes, however, where a panel is to be subjected to HIGH STRESS, you may prefer to use the riveted and bolted type of mounting. In that case, you must take a few precautions.

Use as many bolts or rivets as practical.

Distribute the total stress as evenly as possible along the bolts or rivets.

Drill the holes in the plastic LARGER than the diameter of the bolt or rivet. This permits the plastic to expand and contract without breaking.

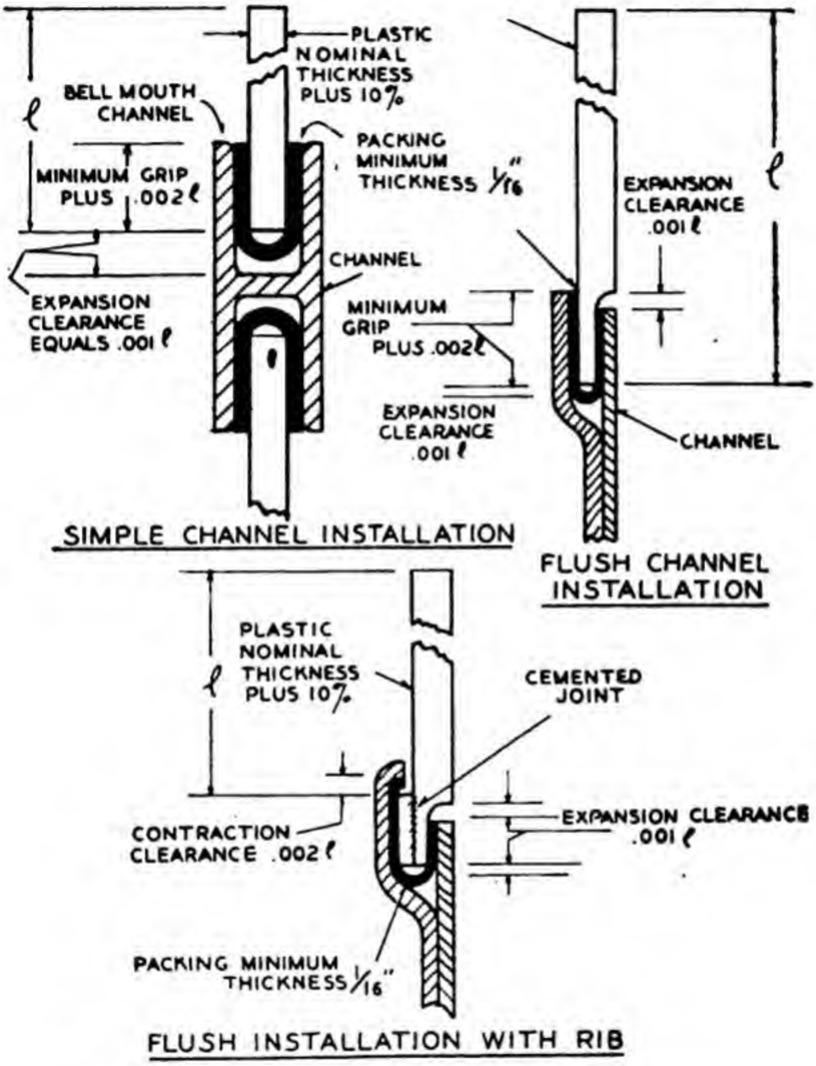


Figure 235.—Typical mountings.

Drill the holes in the plastic concentric with the rivet or bolt and the window frame. Otherwise expansion will cause bending at one edge of the hole.

Use TUBE SPACERS like those in figure 236 or some similar device to protect the plastic from direct or too much pressure.

PACKING is used on either side of a plastic sheet in a channel or window frame for three reasons. It makes the installation or mounting waterproof. It reduces vibration. It takes care of the variation in thickness between the plastic and the mounting.

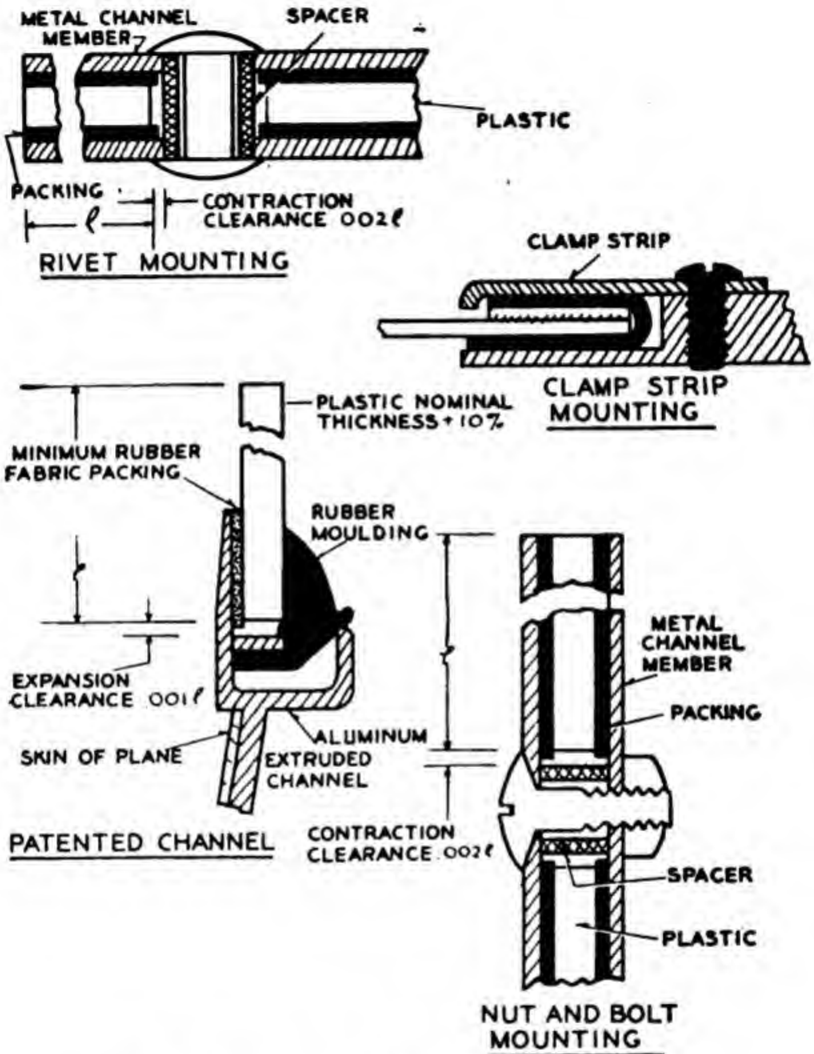


Figure 236.—More typical mountings.

Packing doesn't PREVENT high stress, but rather TRANSFERS it from one area to another. Common types of packing are synthetic rubber, natural rubber, cork, felt, fabric, or combinations of these materials. If you use rubber, it should be soft and approximately .060 inch thick. Be sure, if you pick other types of pack-

ing, to see that they don't contain SOLVENTS for the plastic being used.

Different types of mountings will require varying specifications. But these specifications must all include the following items.

There must be a minimum edge distance so that the panel will fit into the channel.

You must make allowance for expansion and contraction of the plastic.

There must be a minimum thickness of packing.

An acrylate plastic 12 x 12 inches in area should extend into the channel .625 inch plus contraction clearance. (The contraction clearance is .002 inch per inch of panel width.)

Larger panels should extend 1.000 inch plus contraction clearance.

There are a number of things you should take into account in figuring how thick a plastic panel should be for a window. For example, a square panel should be thicker than a long narrow panel of the same area. Another thing—bends in the plastic add to its strength and rigidity.

If ribs are to be cemented to the plastic, you can make the panel of thinner material. Deeper channels also permit the use of thinner panels. If the edges are routed, however, a thicker sheet will be required.

Another factor which determines the thickness of the panel is the AMOUNT OF PRESSURE to which it will be subjected. The pressure, of course, depends upon the location of the panel and on the speed of the airplane.

Here is the general rule for deciding upon the thickness of a plastic panel—

Use the SAME THICKNESS as on the original when making a replacement, unless special factors enter the case.

When installing a panel, make the proper allowance for THERMAL EXPANSION of the plastic. And remember, the width of the channel should be great enough

to allow PACKING to be inserted on each side of the sheet of plastic.

Avoid excessive tightening of bolts or rivets. Tighten nuts up snugly; then back them off ONE FULL TURN.

For installation purposes, the area to be covered decides the thickness of the sheet which you will use. For panels not subjected to high stresses, the thicknesses given below are all right for the area listed.

THICKNESS OF PLASTIC SHEET

Thickness	Maximum Recommended Area
.060	6" x 6"
.080	12" x 12"
.100	18" x 18"
.150	24" x 24"

How Well Do You Know—

AIRCRAFT METAL WORK

QUIZ

CHAPTER 1

METAL PROCESSES

1. What type of coating makes galvanized iron out of sheet iron?
2. Where is galvanized iron commonly used in aviation metal work?
3. (*a*) What kind of seam is best for constructing such galvanized iron objects as funnels and tanks?
   (*b*) What other seams are commonly used with galvanized iron?
4. How would you make a wire edge?
5. What tools or machines would you use to cut large pieces of metal along straight lines? Curved lines?
6. What is the easiest way to cut small holes in metal? Large ones?
7. Name five types of sheet metal stakes and mention some of their uses.
8. How would you bend metal stock to form a cylinder?
9. (*a*) What are the names of the two kinds of metal-bending machines?
   (*b*) What is the basic difference between them?
10. How would you make a burred edge?
11. (*a*) How does a slip-forming machine work?
    (*b*) How do you adjust its rolls for making a tapered shape?
12. What advantage does a pneumatic drill have over an electric drill?
13. At what angle do you hold a drill when you're piercing a flat or rolled surface?
14. Is it smart to put pressure on a drill when cutting?

CHAPTER 2

FORMING ALUMINUM

1. Why is aluminum such a popular aircraft metal?

2. What is the purpose of annealing?
3. What are two types of treatment used to prevent corrosion?
4. (*a*) What kind of hammer is used to smooth the surface of parts after they have been formed?
   (*b*) What other tool do you need to use with this hammer?
5. What types of aircraft aluminum will withstand the greatest amount of shrinking and stretching? Why?
6. What tools do you use to take out bumps?
7. (*a*) What is a "hold down plate" for?
   (*b*) How do you use it?
8. What surface condition on the material indicates that the material needs annealing? What are some other signs?
9. In flanging, why do you need a backup tool?
10. Why are the edges of lightening holes in sheet metal often flanged?
11. What is the purpose of sandbag bumping?
12. What tools do you need to joggle an angle strip?
13. (*a*) What is a bend radius? (*b*) A bend tangent?

CHAPTER 3

RIVETING

1. (*a*) Which type of rivet head offers the least resistance to airflow?
   (*b*) Name another type which offers little resistance to airflow, and is particularly adaptable for use in thin sections.
   (*c*) What are the other basic types of rivet heads?
2. "Decode" these rivet symbols—
   (*a*) AN442D–3–4.
   (*b*) AN430DD–4–5.
   (*c*) AN456AD–4–5.
   (*d*) AN425AD–5–6.
3. If you are holding in your hand the four rivets designated in question 2 above, on which rivet head will you feel a raised dot?
4. How will the others be marked?
5. Which of the rivets in question 2 have to be heat-treated before they can be used?

6. What factor determines the selection of the correct diameter rivet?
7. How do you decide how long a rivet should be used for a particular job?
8. (*a*) What is the absolute minimum edge distance for rivets?
   (*b*) In actual practice, how much space is generally left between rivets?
9. (*a*) How do A17S–T rivets compare with 17S–T rivets in strength?
   (*b*) When you select rivets of one alloy to replace rivets of a stronger material, what rule must you follow?
10. How do you select the right riveting gun for a particular job?
11. Name four different kinds of bucking bars.
12. How do you rivet by hand?
13. Why is it always a good idea to check the air inlet and hose fittings before you start to use a pneumatic riveter?
14. What is the most efficient type of rivet set?
15. What does "psi" mean?
16. In the salt bath, do the rivets come in contact with molten salt?
17. How long does it take to age harden rivets?
18. What is the main advantage of flush riveting?
19. Describe what is meant by dimpling.
20. What is the distinctive feature of a cherry rivet?
21. What are the two types of cherry rivets?
22. What type of cherry rivet does the Navy use?
23. Are cherry rivets as strong or stronger than *AD* rivets of the same diameter?
24. What is the big advantage of explosive rivets?
25. In the new type of explosive rivet, does the shank expand after the explosion?
26. What tools do you need to install and expand explosive rivets?
27. If an explosive rivet does not expand, can you use it again?

CHAPTER 4

FASTENERS

1. Are any fasteners retained as permanent parts of an aircraft structure?

2. What are Cleco sheet fasteners used for?
3. How do you determine the size of machine screws?
4. What are some of the restrictions on the use of machine screws?
5. What are *PK*'s?
6. (*a*) How are anchor nuts fastened to the sheets they hold in place?
(*b*) On what sort of structures are anchor nuts most commonly used?
7. What is the difference between anchor nuts and channel gang nuts?
8. What are some of the valuable characteristics of Dzus fasteners?
9. What are rivnuts? Where are they most commonly used?
10. Why is it a good idea to use a plug screw with a rivnut even if no part is attached?
11. (*a*) What is the basic difference between a Dill lok-skru and Dill lok-rivet?
(*b*) How do Dill lok-skrus and lok-rivets differ basically from rivnuts?
12. How big a turn does a Camloc fastener require to open or close?
13. What are the three parts in a large-size Camloc fastener?
14. How do you peen a Cam fastener?

CHAPTER 5

STRUCTURAL REPAIRS

1. What kind of metal should be used for watertight patches?
2. How should rivets be placed when a double row of rivets is used?
3. (*a*) What is done to a lap patch to assure a tight fit?
(*b*) How much should a lap patch overlap the hole?
4. Briefly outline the riveting procedure for making skin repairs.
5. (*a*) How should small cracks in non-stressed and stressed skin be repaired?
(*b*) How about the procedure for repairing small holes in stressed and non-stressed skin?

6. What short method is used to determine the number of rivets required on each side of a patch for stressed skin repair?
7. (*a*) What are filler splices and insertion splices used for? What is the difference between them?
   (*b*) What should be the size and shape of a filler splice?
8. (*a*) How long must the reinforcement for a filler splice be?
   (*b*) How can splice stock be made if no extruded stock is available?
9. In making a splice, how do you determine—
   (*a*) The size of rivet to use?
   (*b*) The rivet pattern?
10. (*a*) What are spars?
    (*b*) What are three types of ribs?
    (*c*) Outline the general repair procedure followed in making repairs to spars, ribs and bulkheads.
11. (*a*) What materials are used for trailing edges?
    (*b*) Why is there considerable chance for corrosion on a trailing edge?
12. (*a*) Why is 3D rivet spacing not necessary for a trailing edge splice?
    (*b*) What should the spacing be?
13. (*a*) How is a crack on a trailing edge repaired?
    (*b*) How is a large area in a damaged V-angle channel-type trailing edge repaired?
14. For what would you use a hole finder?
15. What types of damage should you look for in inspecting damaged skin area?

CHAPTER 6

TANKS

1. Where can you find detailed instructions for repairing any tank?
2. (*a*) What general methods may be used in repairing aluminum tanks?
   (*b*) Which of these methods cannot be used for repairing integral tanks? Why?
3. (*a*) How do you clean a metal tank before welding it?

(*b*) How does this cleaning procedure differ from that to be used if you repair by soldering? By riveting?

4. Why should integral tanks be refilled as soon as possible after they are emptied?
5. Which of the three parts of a self-sealing fuel cell provides the sealing effect?
6. What is the chief purpose of the repair of self-sealing fuel cells?
7. What are the five types of repairs to self-sealing fuel cells?
8. How deeply should the outside surface be buffed for a permanent blister repair?
9. How many hours before using can cement be mixed?
10. How can you tell when the cement on the patch, or the surface on the cell, is ready for another coat or for applying the patch?
11. In removing a cell, what is the next step after all hose, tubes, and fittings have been disconnected?
12. Whenever possible, should sloshed type fuel cells be sent back to the factory for repairs?
13. What is the maximum time a man should work alone in a cell?
14. How high may cells packed in cartons be stacked?

CHAPTER 7

TUBING

1. How may tubing used in modern aircraft be classified?
2. What aircraft tubing must be flexible?
3. How is flexible tubing measured?
4. Why must the ends of tubing be cut square before flaring?
5. Why has aluminum alloy largely replaced copper as tubing material?
6. What is the general rule for quenching copper tubing after annealing?
7. What color band is used on fuel lines? On lubricating oil?
8. On a hacksaw blade used for cutting rigid tubing, how many teeth should there be to the inch?
9. What is the minimum bend radius for a copper line ½ inch in diameter?

10. How should tube bending filler alloys be heated?
11. What is the advantage of the "triple tube" type of fitting?
12. Which aluminum alloy is most widely used for tubing?

CHAPTER 8

PLASTICS

1. Plastics are classified into 2 groups, according to their reactions to heat. What are those groups?
2. (*a*) What are the two main types of transparent plastics?
   (*b*) What are the three methods for distinguishing between these main types?
3. (*a*) What are some of the precautions to be observed in storing plastics?
   (*b*) How are plastics protected for storage?
   (*c*) How should masking paper be removed from plastics?
4. (*a*) What are the methods of cleaning transparent plastics?
   (*b*) What protective coating is given the plastic after cleaning?
5. (*a*) What compounds are used on buffing wheels for plastics?
   (*b*) What is the buffing procedure?
6. (*a*) What type of saw blade is used for sawing plastics?
   (*b*) At what speed should a saw blade run when sawing plastics?
7. What is the procedure for sanding plastics?
8. (*a*) What types of drills are used for drilling plastics?
   (*b*) What are the correct angles of a drill point for drilling plastics?
   (*c*) What are some of the precautions to be observed in drilling?
9. What are the precautions to be observed in tapping and threading?
10. What is the first thing to do when you detect a crack in transparent plastics?
11. How may bullet holes in plastics be repaired?
12. (*a*) How may plastics be joined?
    (*b*) What are the names of the most common types of cements used on acrylic plastics?

(*c*) What precautions must be observed when mixing or storing these cements?

(*d*) What are the two methods of cementing?

13. What are two types of forming used with plastics?
14. (*a*) What methods may be used for heating plastics?

    (*b*) What is the temperature range for monocurve forming of acrylate plastics?
15. What are some of the precautions to be observed when using nut, bolt, or riveted mountings?
16. What are the three reasons packing is used for installations?

ANSWERS TO QUIZ

CHAPTER 1

METAL PROCESSES

1. Zinc.
2. Laying out templates.
3. (*a*) Grooved seam.
   (*b*) Standing seam and lap seam.
4. Bend metal around wire or rod by hand, or by using bar folder.
5. Hand shearing snips, squaring shears. Unishear.
6. Punching machine. Combination scroll and circular shear, or the aircraft snip.
7. Check your answer against pages 00 and 00.
8. Use a hollow mandrel stake and bend around, using hand and mallet.
9. (*a*) Folders and brakes.
   (*b*) Folders limit the width of the bend, whereas brakes do not.
10. Use a burring machine, set and aline properly, and turn disk carefully through the rolls.
11. (*a*) It uses three rolls. Two feed the sheet through, and the third serves as an idler to shape the metal as it comes through.
    (*b*) Set the rear roll so that the rolls are closer together at one end than at the other.
12. Better control (achieved by varying input of air).
13. Perpendicular to surface.
14. No. You may break the drill.

CHAPTER 2

FORMING ALUMINUM

1. High strength to weight ratio. In other words, it's light but strong.
2. To soften metal for greater ease in forming.
3. Coating or anodic.
4. (*a*) Planishing hammer.
   (*b*) Forming block.
5. Fully annealed 2S, 3S and 52S. They are extremely soft materials.
6. Mallet, form block, template, and hold down plate.
7. (*a*) To keep the metal in place and to make sure that it is securely in contact with the form block while it is being bumped.
   (*b*) Fasten it with clamps (not too tightly) to hold metal to form .block.
8. Grainy appearance. Springiness of the material, ringing tone when struck, or increased resistance to forming.
9. To raise the creases which form on the outer edge of the flange as the metal is hammered.
10. To help stiffen the area around the hole.
11. To form metal where a flexible bag will give better results than a solid formblock.
12. A specially designed joggling block, vise, and mallet.
13. (*a*) The curvature at the bend of a piece of metal.
    (*b*) Line where bend begins.

CHAPTER 3

RIVETING

1. (*a*) Countersunk.
   (*b*) Brazier.
   (*c*) Flat head and round head.
2. (*a*) AN442D–3–4
   Length ($4/16$ inch)
   Diameter ($3/32$ inch)

Alloy (17S)
Head shape (Flat)
Army-Navy specifications

(*b*) AN430DD–4–6
Length ($\frac{6}{16}$ inch)
Diameter ($\frac{4}{32}$ inch)
Alloy (24S)
Head shape (Round)
Army-Navy specifications

(*c*) AN456D–4–5
Length ($\frac{5}{16}$ inch)
Diameter ($\frac{4}{32}$ inch)
Alloy (A17S)
Head shape (Brazier, modified)
Army-Navy specifications

(*d*) AN425AD–5–6
Length ($\frac{6}{16}$ inch)
Diameter ($\frac{5}{32}$ inch)
Alloy (A17S)
Head shape (Countersunk)
Army-Navy specifications

3. The one in (*a*).
4. (*b*) head will have two raised bars on opposite sides.
   (*c*) and (*d*) heads will be dimpled.
5. (*a*) and (*b*).
6. The thickness of the section through which the rivet is to be driven.
7. The correct length of the rivet should equal the sum of the thickness of the metal plus $1\frac{1}{2}$ times the diameter of the rivet shank.
8. (*a*) Twice the rivet diameter. ($2\frac{1}{2}$ times countersunk rivet diameter.)
9. (*a*) 17S-T rivets are stronger.
   (*b*) The new rivets must be a size larger than the rivets they replace.
10. Consider the size and type of alloy of the rivets and the accessibility of the place into which the rivets are to be driven.
11. Any four of these: angle, stringer, skin, torpedo, flange, diamond point, nut plate, offset, duck bill, tube.

12. Drill your holes and insert rivet of right size and material. Place metal to be riveted over bucking block with rivet head in cup. Now strike rivet end with hammer.
13. See that they are free from foreign particles.
14. A short, straight set.
15. Pounds per square inch.
16. No.
17. Four days.
18. Reduces airflow resistance.
19. Pressing metal around a rivet hole to the proper shape by using dies.
20. It can be inserted and secured "blind" (one side only).
21. The hollow type and self-plugging type.
22. The self-plugging type.
23. No, weaker.
24. It can be inserted and exploded from the outside only.
25. Yes.
26. Explosive rivet gun.
27. No, this is bad practice.

CHAPTER 4

FASTENERS

1. Yes.
2. To hold sheet metal accurately in place during drilling and riveting.
3. By the outside diameter of the threads.
4. Check your answer against page 128.
5. Parker Kalon screws.
6. (*a*) By rivets driven through the flanges which extend from opposite sides of the nuts.
   (*b*) Structures which must be easily detachable.
7. Channel gang nuts are series of anchor nuts inserted in U-type channels, or strips, and held in place by the top ledge of the channel.
8. They are easily installed, readily opened, securely locked, compact, adaptable, and neat in appearance.

9. Rivnuts are internally threaded, one-piece type nuts, machined from 53S-W. They are most commonly used as fastening devices where it would be hard to drive ordinary rivets.
10. Because it will increase strength of the rivnut, prevent wind whistle, and prevent the entrance of moisture.
11. (*a*) The lok-skru is tapped for a screw, whereas the lok-rivet is not.
    (*b*) Lok-skrus and lok-rivets are two piece devices, whereas a rivnut is a one-piece device.
12. Quarter turn.
13. Cam collar, grommet, and stud assembly.
14. With a special Cam punch or a ball peen hammer.

CHAPTER 5

STRUCTURAL REPAIRS

1. An alloy of the same type and temper as the damaged skin.
2. (*a*) They should be staggered, with the rivets of the outer row spaced approximately four rivet diameters apart.
3. (*a*) The edges are crimped to about 15°.
   (*b*) Enough to allow proper edge distance from the rivets.
4. Check your answer against pages 168 to 171.
5. (*a*) Check your answer against pages 171 and 173.
   (*b*) Check your answer against pages 173 and 175.
6. The length of the hole (after ragged edges are cut away) is multiplied by 8 to give the minimum number of rivets required on each side of the patch.
7. (*a*) Replacing damaged length of stringers, a filler splice up to 12 inches in length is backed up with a solid reinforcement splice overlapping the original stringer, whereas insertion splices replace lengths greater than 12 inches by individual reinforcement splices attaching the ends of the 12 inch filler to the original stringer.
   (*b*) In shape it should be like the original stringer, and its length should be $\frac{1}{32}$ inch less than the damaged length but never more than 12 inches.

8. (*a*) Long enough to extend at least four times the width of the stringer on each side of the damaged area.
   (*b*) By forming sheet metal in a brake.
   (*c*) The bend radius of the material being shaped must be kept within the allowance limit.
9. (*a*) The rivet size should be the same as that of the rivets in the original stringer.
   (*b*) The rivet pattern should follow standard riveting rules.
10. (*a*) Members which run the entire length of an airplane wing and carry bending loads imposed on the wing.
   (*b*) Trussed rib, ribs with bent-up sheet flanges and flange holes in the web, and ribs with solid webs and extruded angle or channel stiffening flanges.
   (*c*) Check your answer against page 191.
11. (*a*) Metal and fabric.
   (*b*) Moisture tends to be trapped in the trailing edge when the drainage holes become clogged.
12. (*a*) Because trailing edges are considered non-structural parts.
   (*b*) About 8D.
13. (*a*) By a reinforcement splice.
   (*b*) Check your answer against page 208.
14. Locking rivet holes.
15. Check your answer against page 211.

CHAPTER 6

TANKS

1. Technical notes, Technical orders, specifications, and manufacturers handbooks.
2. (*a*) Welding, riveting, and (if the tank is nickel plated) soldering.
   (*b*) Welding and soldering, because the only way to clean integral tanks is by drying, and drying does not remove explosive fumes.
3. (*a*) Check your answer against page 221.
   (*b*) It is not necessary to clean the tank with water or steam

for a soldering job, provided all fuel or oil has been completely drained, and in riveting repairs the tank should not be cleaned with water or steam.

4. To prevent the drying out of the sealing compound, and the resultant development of leaks, in the empty tank.
5. The middle layer (sealant).
6. To restore to the inner liner its resistance to the action of aromatic fuels.
7. Flat patch repair, build-up repair, seam or lap repair, and blister repair.
8. See table XII.
9. Six to eight hours.
10. When the surface is tacky but no cement sticks to your knuckle after you press it gently against the cemented surface.
11. Collapse the cell by pulling in on the larger surfaces, and then place straps around the cell to hold it in the collapsed position.
12. Sloshed cells should not be repaired. Replace them with new type cells.
13. Never work alone in cells. Always work in pairs.
14. Only so high as to not cause the bottom carton to collapse.

CHAPTER 7

TUBING

1. Structural and non-structural.
2. Any fuel line tubing that is directly connected to the engine.
3. By the inside diameter.
4. If they are not cut square the tube and nut may not seat properly.
5. Because aluminum alloy is light, and does not work-harden as rapidly as copper.
6. Quench it in water if you have a tank large enough to hold the whole section of tubing.
7. Red, yellow.
8. 32.
9. 1½ inches.

10. In a ladle in boiling water.
11. It extends into the fitting a shorter distance than does the two-part type, and therefore is more easily removable.
12. 52S.

CHAPTER 8

PLASTICS

1. Thermosetting and thermoplastic.
2. (*a*) Acrylates (methyl methacrylate) and acetates (cellulose acetate.)
   (*b*) Hardness test.
   Acetone test.
   Burning test.
3. (*a*) Check your answer against page 290.
   (*b*) They are covered with tough masking paper.
   (*c*) It should be lifted at one corner and rolled off.
4. (*a*) Check your answer against pages 292 and 293.
   (*b*) Wax.
5. (*a*) Fine alumina or similar abrasive, used with wax, tallow or grease binder.
   (*b*) Check your answer against pages 294 and 296.
6. (*a*) Check your answer against page 297.
   (*b*) Band saws: 8,000 to 12,000 surface feet per minute. Circular saws (12 inch diameter): Approximately 3,400 rpm.
7. Check your answer against pages 296 and 297.
8. (*a*) Standard metal-use drills, preferably with wide flutes.
   (*b*) 70° lip angle or 140° point angle, and 4° to 8° lip clearance angle.
   (*c*) Use the proper speed and feed.
   Decrease the rate of feed as the depth increases.
   Lift the drill occasionally.
   Use goggles or face shield.
9. Check your answer against page 300.
10. Drill relief holes.
11. Cut out the damaged area and replace it with a plug of thicker material.

12. (*a*) By cementing.
    (*b*) Monomer, monomer solvent, solvent cement, partially polymerized monomer, and solvent polymer cement.
    (*c*) Soak method and wood glue method.
13. Monocurve (simple) forming and multicurve (stretch) forming.
14. (*a*) Electricity, gas, steam, alcohol lamp or blow torch.
    (*b*) 220 to 300° F.
15. Check your answer against pages 300 and 303.
16. It makes the installation waterproof, reduces vibration, and adjusts for the variation in thickness between the plastic and the mounting.

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